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ZOOLOGICA

SCIENTIFIC CONTRIBUTIONS

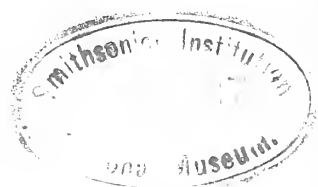
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1.

**A New Crayfish from San Luis Potosi, Mexico.¹
(Decapoda, Astacidae).**

HORTON H. HOBBS, JR.

(Text-figure 1).

The new crayfish here described was taken by the New York Aquarium Cave Expedition to La Cueva Chica, a limestone cave in the State of San Luis Potosi, Mexico. An interesting account of this cave was published by Mr. William Bridges in the *Bulletin* of the New York Zoological Society (Vol. XLIII, No. 3) in June, 1940. In this paper Mr. Bridges mentions the occurrence of crayfish in the cave, and at my request Dr. Charles M. Breder, Jr., of the New York Aquarium, and Mr. Marshall B. Bishop, of the Peabody Museum, have kindly lent me the 34 crayfish taken from the cave, and given me permission to describe them. Upon examining this series I find that while they are closely allied to one of the most common species in the United States, they are distinct.

During December, 1939, an expedition from the Department of Biology of the University of Florida collected in the states of Nuevo Leon and Tamaulipas, Mexico. A fine series of an apparently new subspecies of *Cambarus blandingii* was taken one mile north of Villa Juarez, Tamaulipas, but was not described since the collection contained no first form males.

After having compared specimens of *blandingii acutus* from the southern United States with the Cueva Chica and Tamaulipas *blandingii*, I find that the specimens from Tamaulipas are intermediate between these two, and that the Cueva Chica material represents a new race of *blandingii*.

***Cambarus blandingii cuevachicae*,**
new subspecies.

Diagnosis. *Cambarus blandingii cuevachicae* is a member of the subgenus *Ortmannicus* (i. e.,

the first pleopod of the first form male terminates in four distinct parts, and hooks are present on the ischiopodites of the third and fourth pereopods). Rostrum broad with small lateral teeth. *Areola practically obliterated* (hardly broad enough to bear a single row of punctations). Carapace strongly granulate except along median dorsal surface. First pleopod of first form male similar to that of *C. blandingii acutus*. (See Text-fig. 1, B and D).

Holotypic Male (Form I). Body subovate; compressed laterally. Abdomen narrower than thorax (1.54–1.91 cm. in widest parts, respectively).

Width of carapace greater than depth in region of caudodorsal margin of cervical groove. Greatest width of carapace about midway between caudodorsal margin of cervical groove and caudal margin of cephalothorax.

Areola almost obliterated in middle (hardly broad enough to bear a single row of punctations); cephalic section of carapace about 1.7 times as long as areola (length of areola 35.2% of entire length of carapace).

Upper surface of rostrum deeply excavate; margins slightly convex distad of base, tapering and forming minute tubercles at base of acumen. Acumen short and broad, extending to base of distal segment of peduncle of antennule. Upper surface punctate; lateral margins with setiferous punctations almost to tip of apex. Subrostral ridge not evident in dorsal view. Postorbital ridges terminate cephalad in small tubercles, not spiniform. Suborbital angle absent. Branchiostegal spines present as large acute tubercles.

¹A contribution from the Department of Biology, University of Florida, Gainesville, Florida.

Surface of carapace strongly granulate except on dorsomedian surface of cephalic region; here, with setiferous punctations; one larger acute tubercle on either side in place of lateral spine, which is flanked by two or three slightly smaller ones.

Abdomen slightly shorter than carapace (3.6-3.79 cm.).

Anterior section of telson with one spine in each posterolateral corner.

Epistome broader than long; subminaret shaped; margins not raised; faveolus present at base; small obtuse tubercle on median cephalic border.

Eyes well developed.

Antennules of the usual form with a well developed spine on ventral surface of basal segment.

Antennae reaching to caudal margin of telson. Antennal scale broad (broadest in middle) with a moderately well developed spine on outer distal margin, reaching to distal segment of peduncle of antennule.

First right pereopod long and relatively slender. Hand entirely tuberculate. A single row of eight strong tubercles along inner margin of palm subtended dorsad by two weaker rows and a few scattered tubercles. Very weak ridge present on upper surface of immovable finger. Another weak ridge present on outer distal margin of same finger.

Movable finger of right chela with minute tubercles along distal half of inner margin (crowded on distal third). Lateral margin convex laterad; two distinct rows of tubercles present on lateral margin along proximal two-thirds; an upper row of 24, arising near base of finger, and a lower row of 17 tubercles originating at base of distal three-fourths. A few scattered tubercles present on all surfaces near base of finger. Proximal two-fifths of outer margin with five tubercles. Distal upper, lower, and mesial surfaces setose punctate.

Immovable finger of right chela with minute denticles on distal two-thirds (crowded on distal third). Mesial margin concave laterad; two distinct rows of tubercles on mesial margin: the upper row with 20 tubercles along the proximal two-thirds (the fifth is decidedly larger and more conspicuous than the others) and the lower row of 13 along the proximal three-fourths (the seventh is decidedly the largest of this row). When the fingers are brought together the large tubercle on the upper side of finger lies over the movable finger and the large one on the lower row extends beneath it.

Carpus longer than wide, much shorter than inner margin of palm of chela; shallow irregular furrow above. Mesial and upper mesial surfaces tuberculate; four large spike-like tubercles on mesial distal half; upper lateral, lateral, and ventral surfaces with setiferous punctations.

Merus with dorsal, ventral, distal mesial, and distal lateral surfaces tuberculate; proximo-

mesial and proximolateral surfaces with a few scattered punctations. Fourteen tubercles in a row on upper margin. Lower mesial margin with a row of 19 tubercles, and lower lateral margin with a row of 15 tubercles.

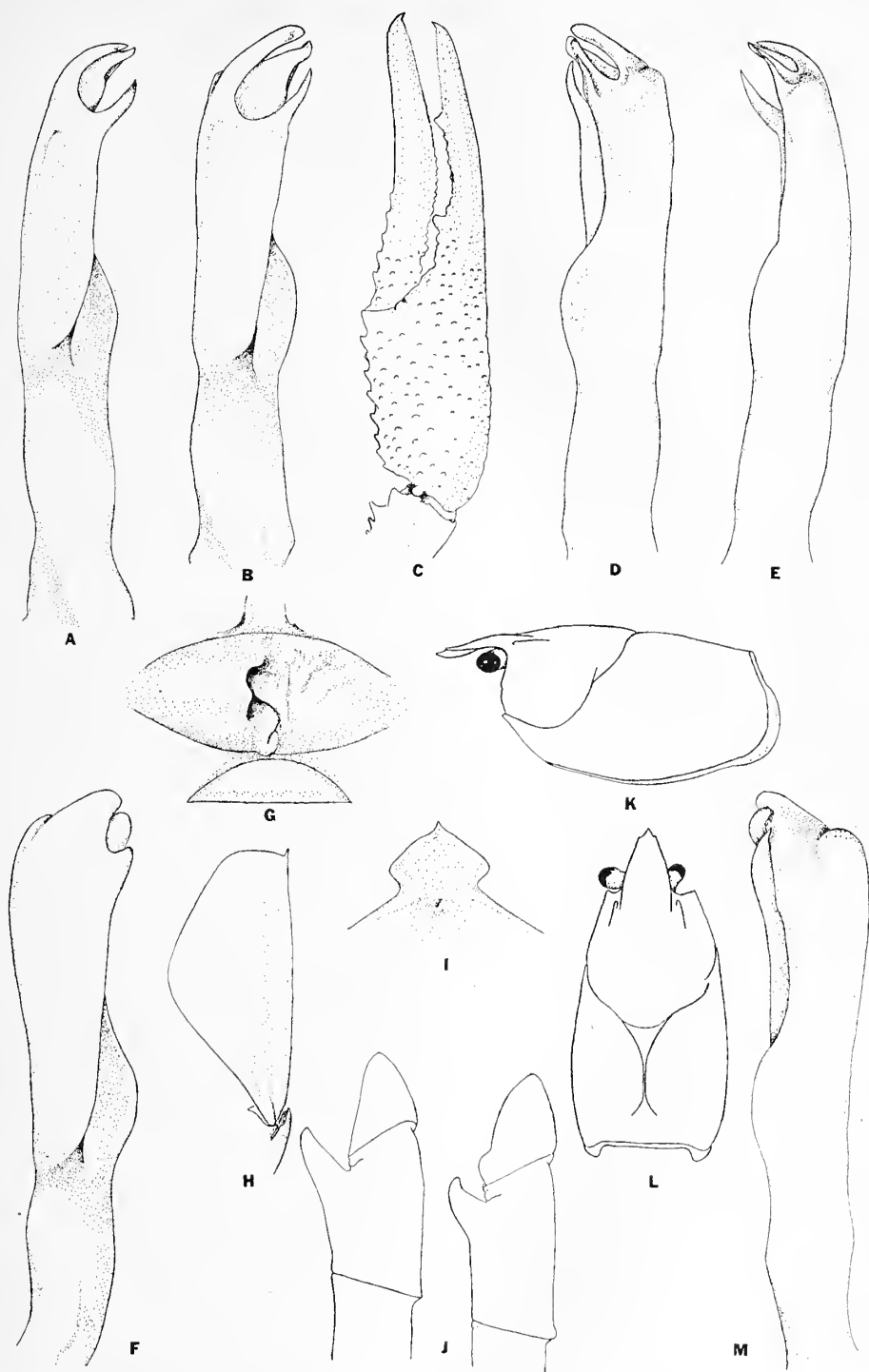
Hooks on ischiopodites of third and fourth pereopods. Both hooks are slender and simple.

Coxopodite of fourth pereopod with a large knob-like protuberance on caudomesial margin.

First pleopod extending almost to coxopodite of second pereopod when the abdomen is flexed. Tip terminating in four distinct parts. The mesial process is subspiculiform and is directed distad and laterad; is exceeded by the other processes distad. The cephalic process is corneous and blade-like, somewhat rounded distad, and extends distad of the other processes; it partially overhangs the central projection. The caudal process, the least conspicuous of the four distinct terminals, lies along the caudo-lateral margin of the central projection and extends barely distad of the mesial process. This (the caudal) process is corneous, and its tip is acute. The central projection is the largest of the terminal elements; it is corneous, concave mesiad and somewhat twisted. This projection is made up of two parts, the centro-cephalic which arises just cephalad of the caudal process on the lateral surface, and the centro-caudal which is somewhat larger and forms the mesial face of the central projection. These two processes are fused along an oblique line visible in lateral and caudo-lateral views only. On the lateral surface of the appendage a conspicuous knob bearing long setae arises at the base of the cephalic process.

Male Paratype (Form II). Differs from the male holotype in the following respects: Height of carapace greater than width (1.50-1.31 cm.). Postorbital ridges terminate cephalad in small acute tubercles. Branchiostegal spines moderately strong. Antennae reach anterior section of telson. Chelae smaller with less well defined tubercles, double row present on lateral margin of movable finger only. First pleopod terminating in four distinct parts; none corneous nor as sharply defined as in the first form male. (See Text-fig. 1, F and M). Hooks on ischiopodites of third and fourth pereopods much reduced.

Female Allotype. Differs in the following points from the first form male, holotype: Width of carapace slightly less than depth. Right subrostral ridge barely evident just caudad of base of acumen. Branchiostegal spines moderately strong. Lengths of abdomen and carapace subequal. Anterior section of telson with two spines in right posterolateral corner and none in the left (broken). Epistome slightly broader and shorter than in male. Antennae reaching fifth abdominal segment. Chelae smaller and tubercle count differing—only one row of tubercles on each opposing margin.



Text-figure 1.

Cambarus blandingii cuevachicae, new subspecies. Pubescence has been removed from all structures illustrated. Figures not otherwise indicated are of *C. blandingii cuevachicae*. A, mesial view of first pleopod of *C. blandingii acutus* from Louisiana; B, mesial view of first pleopod of holotype; C, right chela of holotype; D, lateral view of first pleopod of holotype; E, lateral view of first pleopod of *C. blandingii acutus* from Louisiana; F, mesial view of first pleopod of male, form II; G, annulus ventralis of allotype; H, antennal scale of male paratype; I, epistome of male paratype; J, ischiopodites of third and fourth pereopods of first form male paratype; K, lateral view of carapace of holotype; L, dorsal view of carapace of holotype; M, lateral view of first pleopod of male, form II.

Annulus ventralis subovate, elongate along transverse axis. Fossa projects beneath median dextral wall; sinus curving sinistrad slightly sinistrad of midventral line where it turns caudad to cut the caudal margin of the annulus. A shallow longitudinal furrow is present sinistrad of the midventral line across the face of the annulus. Sternum just cephalad of annulus bearing a low tubercle on either side of the midventral line. Sternum just caudad of annulus modified into a low flat semioval structure.

Measurements. Holotype: carapace, height 1.71, width 1.86, length 3.79 cm.; areola, width .02, length 1.38 cm.; rostrum, width at base 1.59, length 1.89 cm.; abdomen, length 3.6 cm.; right chela, length of inner margin of palm 1.42, width of palm 1.14, length of outer margin of hand 4.23, length of movable finger 2.53 cm. Female Allotype: carapace, height 1.87, width 1.85, length 3.83 cm.; areola, width .07, length 1.36 cm.; rostrum, width at base .64, length .89 cm.; abdomen, length 3.72 cm.; right chela, length of inner margin of palm .92, width of palm 1.00, length of outer margin of hand 2.86, length of movable finger 1.85 cm.

Type Locality. La Cueva Chica, a limestone cave, about one mile northeast of Pujal, San Luis Potosi, Mexico. These specimens were collected above the first waterfall. "Tumbled rocks alternated with shallow, narrow puddles. The going was difficult, but in the second puddle we forgot all about that, for Bishop spotted another crayfish. This time there was no escape, for the pool was scarcely a yard wide and twice as long. A couple of grabs and he had the creature.

"It was not blind. Lighter in color than the normal crayfish of the outside waters, it was fully eyed and of the common local species. That was a disappointment, but it went into the pickling jar anyway."² The temperature of the water was 80° F.

The male holotype and female allotype and a second form male paratype are deposited in the United States National Museum. Of the paratypes, a male, form I, one male, form II, and a female are in my personal collection; one male, form I, seven males, form II, ten females, four immature males, and six immature females are in the Peabody Museum, New Haven, Connecticut.

Relationships. *Cambarus blandingii cuevachicae* is most closely allied to *C. blandingii acutus*. Specimens collected one mile north of Villa Juarez, Tamaulipas, Mexico, seem to be somewhat intermediate between these two, particularly in respect to the width of the areola.

Remarks. I have been unable to discover any peculiarities in this race that seem to be associated with cave life. Bridges has pointed out that these specimens were of lighter color than the "normal crayfish of the outside water." I have seen only preserved specimens so I cannot attest this observation.

On the hairy parts of the ventral surface of these crayfish were found numerous ostracods, *Entocythere cambaria* Marshall, and many branchiobdellid worms, *Cambarincola macrodonta* Ellis.³

² *Bull. N. Y. Zool. Soc.* 43 (3): 84-85. May-June, 1940.

³ Dr. Clarence R. Goodnight kindly identified this branchiobdellid for me.

2.

A New *Corydoras* from Brazil.

F. R. LAMONTE

American Museum of Natural History.

Through the courtesy of the New York Aquarium, we have secured three living specimens (approximately 15 mm.—18 mm. standard length), and seven preserved specimens (13 mm.—19 mm. standard), of a Brazilian *Corydoras* apparently hitherto undescribed.

These fishes formed part of a collection brought to New York by Mr. Auguste Rabaut, and collected by him toward the end of December, 1940, in a tributary of the Amazon. The collector never heard a name given the stream, but he reached it after seven days by river boat west from Manaos, and four more days' journey north toward the Colombian border. The country was flooded swamp, with heavy vegetation. Mr. Rabaut reports that the water was extremely acid.

The specimens appear to represent two color patterns of the same species, the change in pattern probably occurring with growth. Each pattern, in certain lights, shows traces of the other. Of the three living fishes, the two larger are the "striped pattern;" of the preserved specimens, six are the "half and half" pattern, and the 19 mm. specimen is striped.

Corydoras rabauti, new species.

Description of Type. Number 15644, American Museum of Natural History, collected December, 1940, in a tributary of the Amazon River, by A. Rabaut.

Differences in body proportions of the 19 mm. striped specimen are noted in parentheses.

Length to base of caudal, 15 mm. A rather chunky fish, with a short, rounded snout; the bony interorbital contained twice in the snout. There is no black hastate spot at the base of caudal, and the width of the naked area on the breast between the coracoids is equal to the diameter of the eye. The suborbital does not cover the entire cheek. The coracoids do not completely surround the pectoral bases on the surface of the body. The dorsal does not reach the adipose when laid back. The depth of the suborbital is equal to the diameter of the eye; the dorsal spine equal to the length of the snout. The flesh of the abdomen is smooth, without platelets.

Snout, 2.1 in the head, its profile convex, sloping gently; interorbital, 2 (1.8); eye, 3.1. Body depth in standard length, 3 (2.7); width, 3.4 (3.1); head, 2.7 (3); snout to origin of dorsal, 1.8 (2). Depth of caudal peduncle in body depth, 1.4. Lateral scutes spinous, 18–20/17–20 (20/21). Lateral line pores are visible on the first two or three scutes only. The abdomen is not granular and there are no platelets.

Fontanel elongate, oval, reaching two-thirds the way to the anterior margin of eye and, posteriorly, to the supra-occipital process. Occipital process very narrowly triangular, not reaching azygous predorsal scute. Rictal barbels just reaching the gill-opening.

Dorsal I, 8; the spine 1.8 (1.5) in the head. The fin is rounded, the first few rays longer than the spine. Distance of the dorsal fin from the adipose, 1.3 in the dorsal base. Anal I, 6, reaching past origin of caudal. Pectoral passing origin of ventrals to about midway in their length; ventrals barely reaching anal. Caudal widely forked, tip of lower lobe slightly rounded.

Color in Life. Head region to short distance in front of dorsal, pinkish-orange. A dull, dark blue streak along anterior margin of eye socket, a short, very narrowly triangular metallic blue streak along posterior margin of pre-opercle. All fins except caudal, which is hyaline, are light orange, the dorsals and ventrals darkest. An ink-blue area, very slightly lighter ventrally, occupies the posterior two-thirds of the body, extending, with a concave anterior marginal outline, from in front of the dorsal origin to in front of the ventrals, entirely around the body, and back to the caudal base. On the caudal peduncle, the dark blue area becomes a short, thin line, margined by two square patches of metallic light blue. The eye is blue. In preservative, the lighter fins are hyaline; the dorsal and ventrals brown; the pinkish-orange body areas are faintly pink, buff or dirty light brown according to the original intensity of color; the lighter blue areas disappear as do the metallic patches; the ink-blue areas are darker and more dense.

In the 19 mm. striped pattern fish (A. M. N. H. Number 15645), the ink-blue area is confined

chiefly to a band, curving upward from the upper half of the caudal peduncle, following the midline of the body, but above it, and rising to a short distance in front of the dorsal origin. There are traces of bluish below this stripe on the entire posterior half of the body. The rest of the body is pinkish-orange, darkest on the head. The metallic light blue patches are as in the other fish. There is a trace of bluish on the middle rays of the caudal, not extending to the margin.

In preservative, the body of this fish is creamy, slightly darker on the head, and the ink-blue areas are darker than in life.

The species is very near *egues* (Steindachner, 1877, Sitz. K. Akad. Wien, volume 74, Abt. 1, p. 140. fig.), from which it differs in: a wider interorbital; a wider naked area on breast; a narrower suborbital which does not cover the entire cheek; a larger eye; longer barbels, and an apparently different color pattern.

3.

Notes on Plumage Changes in the Bald Eagle.

LEE S. CRANDALL

Curator of Birds, New York Zoological Park.

(Plates I-IV).

In August of 1930 a young Southern Bald Eagle (*Haliaeetus leucocephalus leucocephalus* (Linnaeus)), just out of the nest and barely able to fly, was captured on Little St. Simon's Island, Georgia, by Philip Berolzheimer, of New York. In December of the same year, the young bird was brought north by Albert C. Benninger, of Brooklyn. It was kept in Forest Park, Queens, New York City, until June, 1931, when it was lent to the Girl Scout camp at Iona Island, Rockland County, New York. On September 2, 1931, the bird was presented to the New York Zoological Park and became the subject of the following notes.

In past years, we had made several attempts to check the progressive plumages of young Bald Eagles but always some catastrophe overtook the bird before the investigation had gone very far. Consequently, on the arrival of this specimen, no notes were made. However, in the autumn of 1933, we were able to plan indoor winter accommodation for the Bald Eagles and were so confident that greater longevity could be obtained that notes on our young individual were made. On October 10, 1933, the bird being three years old and in its fourth year, the body plumage was blackish-brown in general, the breast and lower parts much mixed with white. Forehead and throat were streaked with white, and the tail (Fig. 1) was heavily blotched with gray but with no pure white. The iris was dark brown and the beak greenish-black.

On January 29, 1934, it was noted that the white streaks on the forehead had spread over the entire crown. The throat had become nearly clear white and a band of white extended to the nape. Between this band and the mottled area of the crown, was a parallel dark band, extending from the lores to the nape and passing through the eyes. During the following summer, this pattern was entirely lost. On September 2, 1934, the head, neck and throat were grayish-white, clearest on the throat but elsewhere blotched with blackish-brown, more heavily on the hind neck. The tail (Fig. 2) was extensively blotched with gray but still without clear white. The iris was light brown and the beak had become light

olive, with a hint of yellow. The voice, too, was changing, for while the bird still began his call with the harsh notes of immaturity, he ended with the clear challenge of the adult.

It was during the autumn of 1935, when the bird was five years old and in its sixth year, that it assumed what might be considered its first adult plumage. On November 1 of that year, the head and neck were recorded as pure white. The tail (Fig. 3), also, was now predominately white, although still heavily blotched with blackish-brown. The iris had acquired the pale yellowish-white of the adult and the bill, too, had become clear, pale yellow. The harsh notes had disappeared from the voice, which was now entirely clear.

The tail grown during the summer of 1936 (Fig. 4) was more clearly white but still showed a considerable flecking of blackish-brown, particularly on the shafts. On November 1, 1936, it was noted that while upper and lower tail coverts were mainly white, both were heavily stippled with brown.

In November of 1937, the upper and lower tail coverts were recorded as entirely white. The tail of this year (Fig. 5) showed a considerable reduction in the extent of dark stippling, though this was still present.

In 1938 (Fig. 6), 1939 (Fig. 7) and 1940 (Fig. 8), the markings on the rectrices became progressively reduced. But it was not until 1940, when the bird was ten years old and in its eleventh year, that all stippling disappeared from the vanes. Even then, as may be seen in the photograph of the tail *in situ* (Fig. 8), faint dark markings were still present on the shafts of some feathers.

It seems probable that there may be a considerable individual variation in the extent of dark markings on the shafts of the rectrices. A Bald Eagle received at the Zoological Park on March 1, 1927, had the head and tail "white." Examination of this bird's tail, after its death on June 17, 1940, when it must have been at least eighteen years old, showed heavy streaking of the shafts.

Examination of the dates on which feathers were cast seems to indicate no definite procedure, except that in the last four years the outer pair dropped first and simultaneously or almost so. The earliest date for the casting of the first rectrice was April 19 (1934); the latest, June 21 (1934 and 1936). The earliest date for the casting of the last rectrice was July 30 (1934); the latest, September 25 (1938). Dates assigned to the mounted feathers indicate the time at which they were cast; in each case, they were grown in the previous year. Fig. 8 shows the tail of the living bird on December 12, 1940. The tail was grown in 1940.

SUMMARY.

A Southern Bald Eagle (*Haliaeetus leucocephalus leucocephalus* (Linnaeus)), hatched in

1930, was kept in the New York Zoological Park. In the autumn of 1935, when the bird was five years old and in its sixth year, the head and neck became pure white and the tail nearly so. It was not until 1940, when the bird was ten years old and in its eleventh year, that blackish stippling disappeared from the vanes of the rectrices.

ACKNOWLEDGEMENT.

The dating and mounting of the feathers shown in the accompanying photographs were done by Herbert D. Atkin, who was a Keeper in the Department of Birds of the New York Zoological Park from 1905 to 1940, when he retired on pension. His painstaking cooperation made possible their presentation here.

EXPLANATION OF THE PLATES.

PLATE I.

- Fig. 1. *Haliaeetus l. leucocephalus*. 1933 tail feathers (bird 3 years old; in 4th year) molted in 1934.
 Fig. 2. 1934 tail feathers (bird 4 years old; in 5th year) molted in 1935.

PLATE II.

- Fig. 3. 1935 tail feathers (bird 5 years old; in 6th year) molted in 1936.
 Fig. 4. 1936 tail feathers (bird 6 years old; in 7th year) molted in 1937.

PLATE III.

- Fig. 5. 1937 tail feathers (bird 7 years old; in 8th year) molted in 1938.
 Fig. 6. 1938 tail feathers (bird 8 years old; in 9th year) molted in 1939.

PLATE IV.

- Fig. 7. 1939 tail feathers (bird 9 years old; in 10th year) molted in 1940.
 Fig. 8. Tail feathers of the living bird (10 years old; in 11th year) photographed *in situ* on December 12, 1940.



FIG. 1.

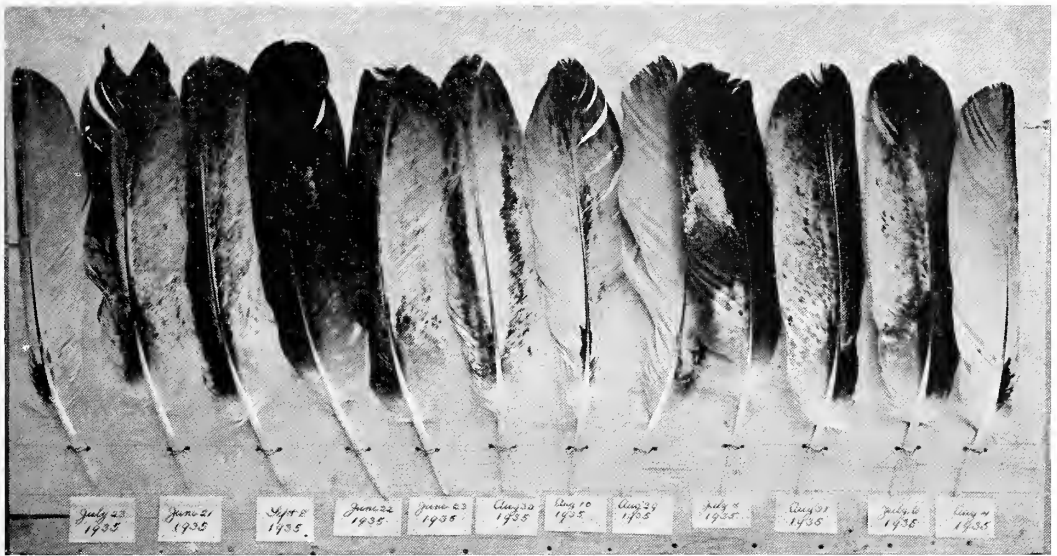


FIG. 2.

NOTES ON PLUMAGE CHANGES IN THE BALD EAGLE.

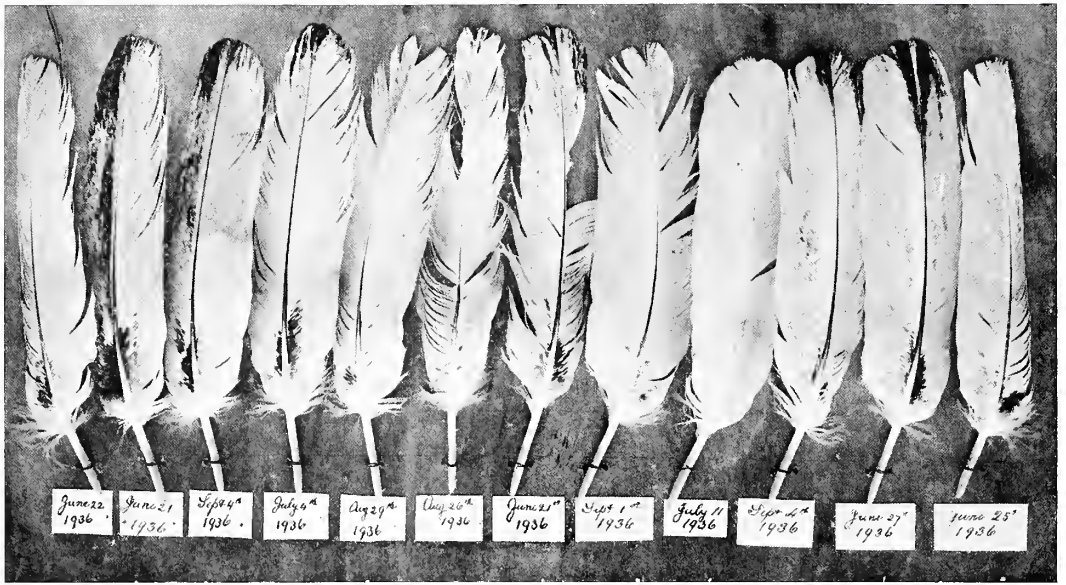


FIG. 3.

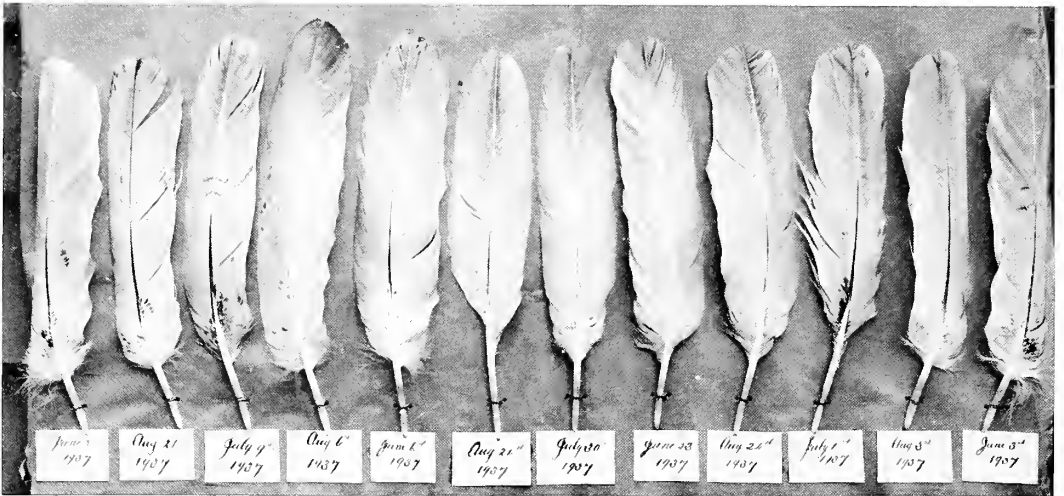


FIG. 4

NOTES ON PLUMAGE CHANGES IN THE BALD EAGLE.

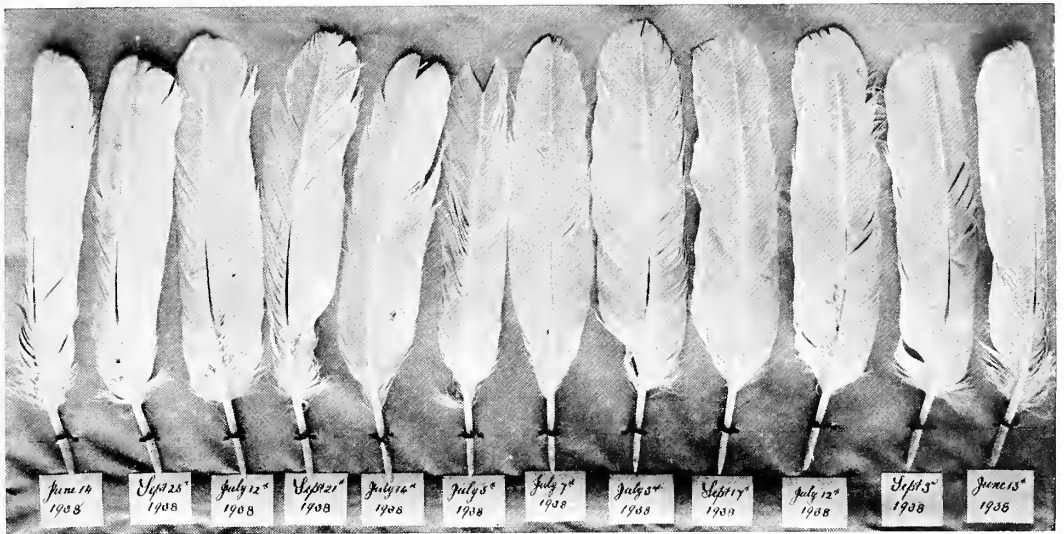


FIG. 5.

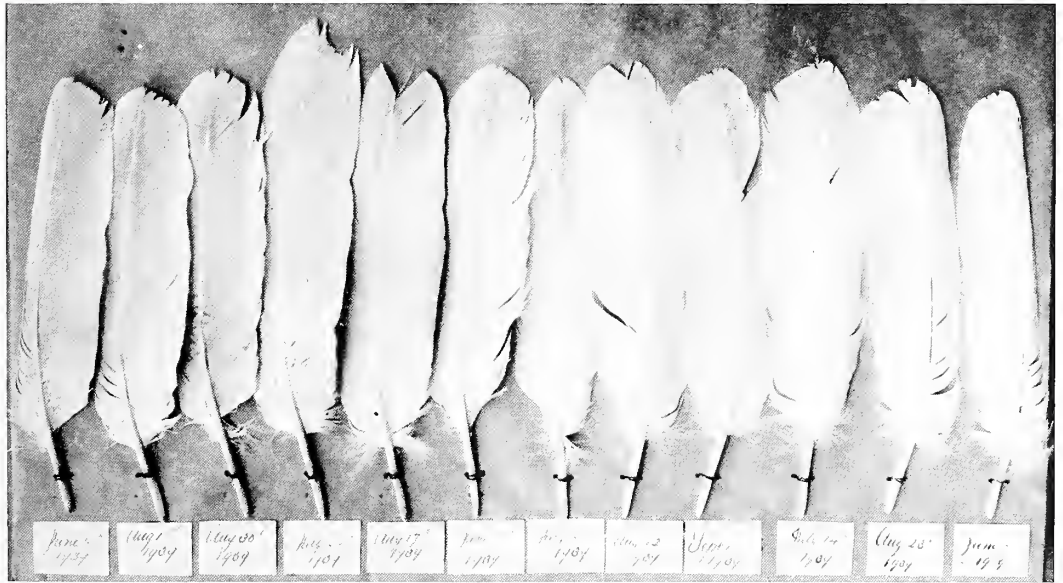


FIG. 6.

NOTES ON PLUMAGE CHANGES IN THE BALD EAGLE.

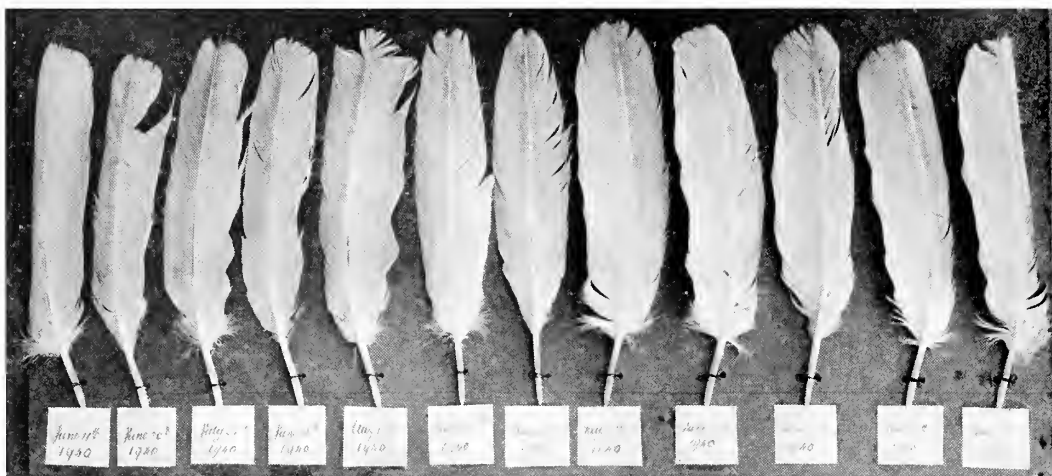


FIG. 7.



BALD EAGLE TAIL FEATHERS
DEC. 12, 1940.

FIG. 8.

NOTES ON PLUMAGE CHANGES IN THE BALD EAGLE.

4.

External Characters of Six Embryo Nurse Sharks, *Ginglymostoma cirratum* (Gmelin).¹

WILLIAM BEEBE

(Plates I & II; Text-figures 1-4).

Six embryo nurse sharks, *Ginglymostoma cirratum* (Gmelin), taken from a single female, have been kindly loaned to me for the study of external characters, by Commodore William K. Vanderbilt. They are borrowed from his marine museum at Huntington, Long Island, and were obtained from Mr. Louis L. Mowbray. The parent was said to be about five feet in length, and was caught in Bermuda. It was not possible to stain or section the specimens, as I agreed to return the embryos in their present condition.

The material consists of six embryos which I have designated as A to F. They are nicely graduated as to size and degree of development, and in total length measure from 73 to 152 mm. They are free, in the sense of being without shells or egg-cases, but each is attached by a short, twisted, umbilical-like extent of tissue with a large, rounded or oval mass of yolk.

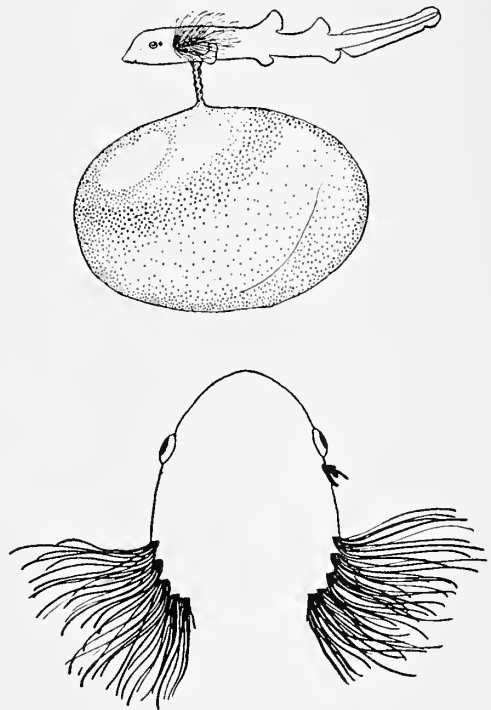
In his recent monograph on *Chlamydoselachus* (Bashford Dean Memorial Volume Archaic Fishes, Article VII, American Museum, N. Y.), Dr. E. W. Gudger writes, "The tropical, shallow-water nurse shark, *Ginglymostoma cirratum* carries in each greatly dilated uterus as many as 21 huge, thick-shelled eggs." As regards the subsequent history of these uterine eggs, Gudger on strong circumstantial evidence believes that this shark is ovoviviparous, and that when the young are pretty well developed, they break out of their shells, and these latter are cast out while the embryos are retained in the uteri during further development. A photograph of one of the unbroken egg-cases, 140 mm. long, is shown on page 560 of the Memorial Volume.

The total lengths of the six embryos under consideration are as follows: Embryo A, 73 mm.; B, 104; C, 107; D, 125; E, 138, and F, 152 mm. The relationship by weight of embryo to yolk is from 5.7% to 33%.

In embryo A the fin-folds are still sufficiently in evidence to confuse any fin base measurements. The first dorsal is joined to the second

dorsal, and this to the caudal, by the continuation of the fin in a groove beneath the surface profile of the body. The same is true of the anal which extends forward in a subdermal groove to the vertical of the pelvics. The translucent dorsal fins in this smallest embryo show thirteen incipient rays in the first, and ten in the second.

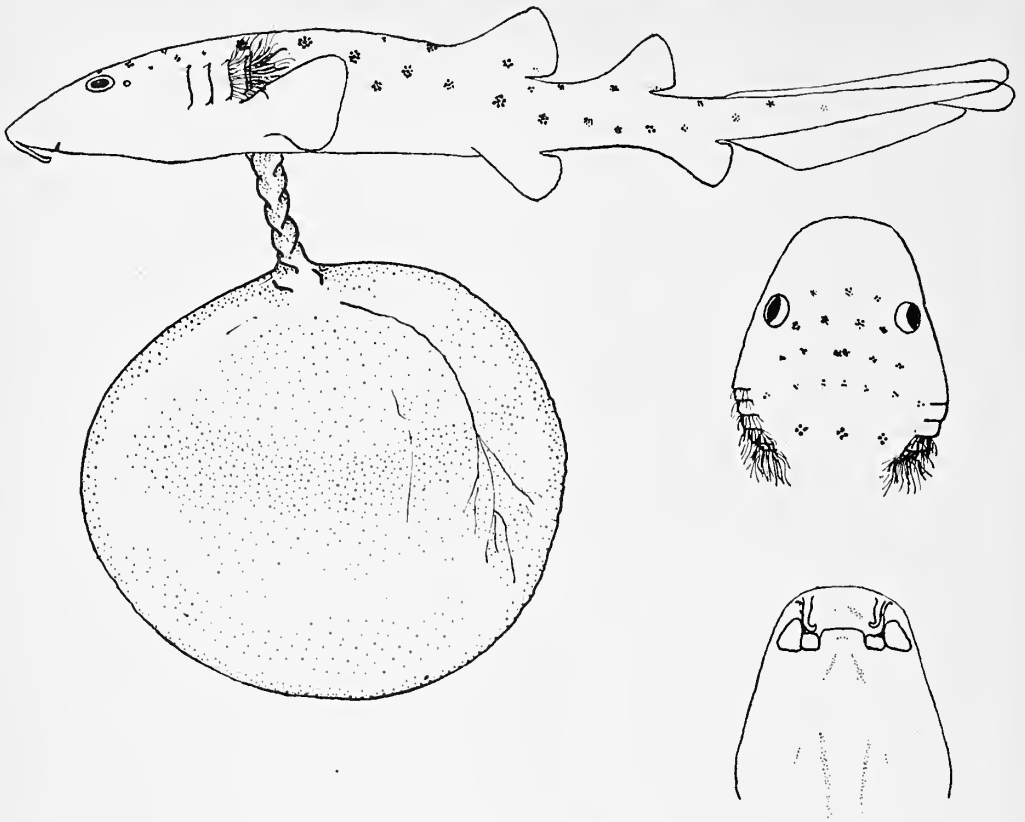
External gills are present in all but embryo F, the largest. There is a gradual absorption in length of these filaments in the first five speci-



Text-figure 1.

Embryo A, length 73 mm. Side view with yolk sac ($\times \frac{3}{5}$). Dorsal view of head showing external gill filaments from spiracle and gill-slits. ($\times 6$).

¹ Contribution No. 612, Department of Tropical Research, New York Zoological Society.
Contribution from Bermuda Biological Station for Research, Inc.



Text-figure 2.

Embryo D, length 125 mm. Side view with yolk sac. Dorsal and ventral views of head.

mens. This is evident in the relationship percentage between gill filaments and total lengths, 20%, 9.6%, 8%, 4.5%, and 3%. The smallest embryo shows the interesting condition of four external gill filaments projecting from the right spiracle, the longest of which measures 1.7 mm. in length. None are visible in the left spiracle.

In the same smallest nurse shark embryo the anterior or first gill-slit shows twenty-six long filaments and a cluster of short ones at the top of the slit. A progressively larger number spring from the next three slits, while the fifth, which is directly below the fourth, has only four filaments, these, however, being of greater length than any of the rest. This general relationship holds good for the larger embryos.

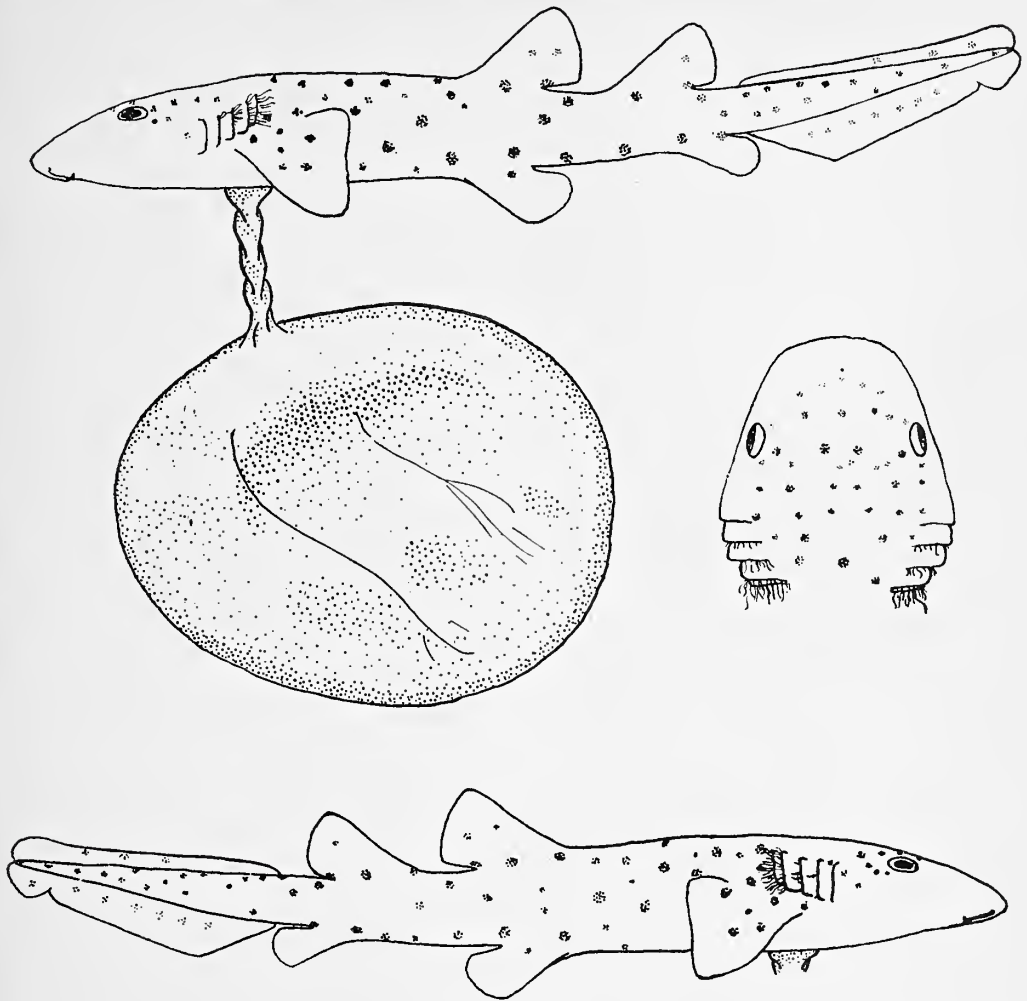
The climax of numerical development of external gill filaments occurs in D, the 125 mm. individual. The next larger, with a total length of 138 mm., has lost all the filaments from the left first and second slits, although they are present on the right side. In E, of 138 mm., this asymmetry is reversed, the right anterior slits being free. The filaments are absorbed from below upward, the last to disappear being close to the dorsal ends of the slits. Those from the fourth and fifth slits are the final ones to vanish.

F, of 152 mm. length, shows no external evidences of filaments. In the two youngest embryos the fifth slit is directly beneath the fourth, but from here on to the adult shark, it is slightly behind the fourth.

As to color and pattern, the 73 mm. embryo is unspotted, as are full-grown sharks. Spots first appear, although weak and sparse, in the 104 mm. individual, and increase in strength and number up at least to embryos of 152 mm. length. In 300 mm., free-swimming nurse sharks the spots are small or obscured by the general dark pigmentation. A 385 mm. specimen taken on the *Zaca* expedition, is immaculate.

Detailed examination shows that the pattern of spots can be quite asymmetrical (specimen C, with seven spots on the right side of the body, and fifteen on the left side); or symmetrical (specimens C, E and F, with numerous transverse bands on the head and body), or somewhat irregular (specimen G). Coppery color is apparent in the irides of the 152 mm. individual.

The smallest and largest of seven specimens (including the six embryos, and a 385 mm. free-swimming young shark), are females. Claspers are evident in all the rest. In the 104 mm. embryo they are 4.5 mm. long, wholly attached



Text-figure 3.

Embryo E, length 138 mm. Right and left side views with yolk sac. Dorsal view of head.

to the inner edge of the pelvic fins, and extending to within 1 mm. of the posterior rim of these fins. There is a gradual increase in size until in the 385 mm. shark the claspers are 13 mm. long, 9 mm. below the posterior fin border, and free for 6 mm. of their length.

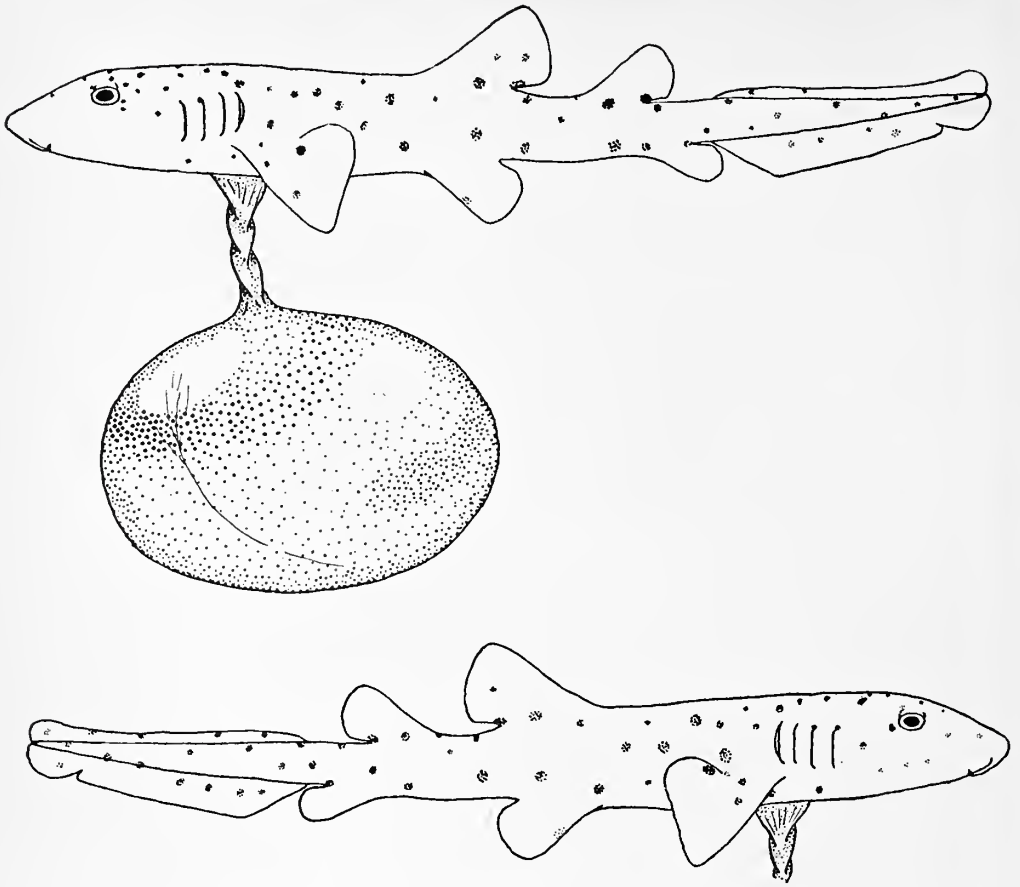
As the cirri or tentacles develop, their tips curve around and down, into the corners of the mouth, inside the lateral flap. This condition also holds in the young, free-swimming sharks, the tentacles being thus partly hidden and protected when not in use.

In the course of embryonic development of *Ginglymostoma* from an embryo of 73 mm. to a full-grown shark of 2,090 mm. total length, we find there are six characters showing a percentage of increase relative to the total length, and seventeen which are on the minus side. The body depth is somewhat greater in the adult, the

general flattening being especially noticeable in unborn individuals. The head, both in length and width, snout, preoral, interorbital and internarial, all show relative reduction in the adult, as much as 3.7% in head length, and 4.4% in the snout. The mouth width, on the contrary, is slightly greater.

The eye, length of tentacle and of spiracle are markedly less in the full grown shark. The heights of the three median fins, first and second dorsals and anal enlarge steadily from early embryo onwards, even reaching a 4.6% increase. The pectorals exceed these, registering width and length increases of 5.7% and 7.6%.

There is considerable reduction in antero-posterior measurements from snout to first and second dorsals, as well as to pectorals, pelvics and anal fins. The bases of all the median fins are relatively less in the adult, partly because of the slow disappearance of the fin-fold.



Text-figure 4.

Embryo F, length 152 mm. Right and left side views with yolk sac.

We may safely deduce that throughout the life of this shark there is an increasing need for large pectorals and a general flattening of the body in relation to the bottom-living habits, while correlated with this is a reduction of the head, with its tentacles, eyes and spiracles, and a relative shortening of the whole body. In fact, *Ginglymostoma* tends in development rather toward a bottom-living, ray-like type, than to a mid-water, shark-like organism.

Developmental characters showing a plus percentage in relation to total length are these: depth

2%, pectoral length 7.6%, pectoral width 5.7%, first dorsal height 4.6%, second dorsal height 2.3%, anal height 1.3% and mouth width 1%. Characters showing minus percentage in development are head 3.7%, head width 1.7%, snout 4.4%, interorbital 4.6%, eye 2%, snout to first dorsal 4.6%, snout to second dorsal 3%, snout to pectoral 4.6%, snout to pelvics 5.2%, snout to anal 3.6%, first dorsal base 2.1%, second dorsal base 2.3%, anal base 3.1%, snout to mouth 2.6%, tentacle length 2.5%, internarial 1.3% and spiracle length .5%.

EXPLANATION OF THE PLATES.

PLATE I.

Fig. 1. Embryo B, length 104 mm. Shark, showing external gill filaments and yolk sac.

Fig. 2. Embryo D, length 125 mm. Shark, showing right side and yolk sac.

PLATE II.

Fig. 3. Embryo F, length 152 mm. Dorsal and right side views and yolk sac.

Fig. 4. Embryo F, length 152 mm. Ventral view and yolk sac.

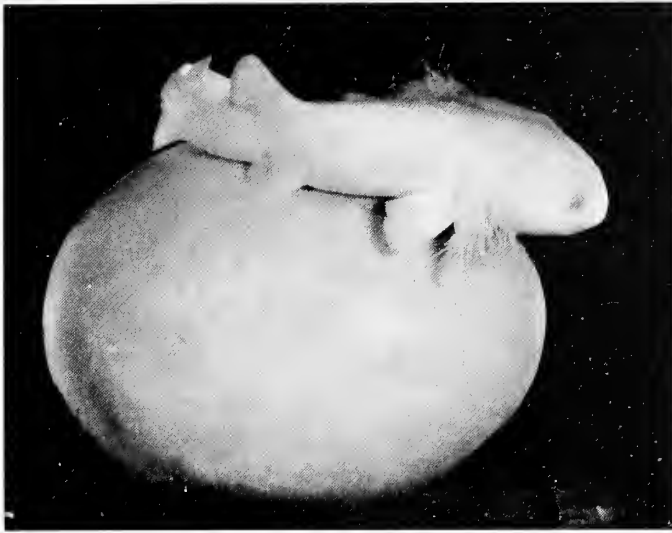


FIG. 1.



FIG. 2

EXTERNAL CHARACTERS OF SIX EMBRYO NURSE SHARKS,
GINGLYMOSTOMA CIRRATUM (GMELIN).

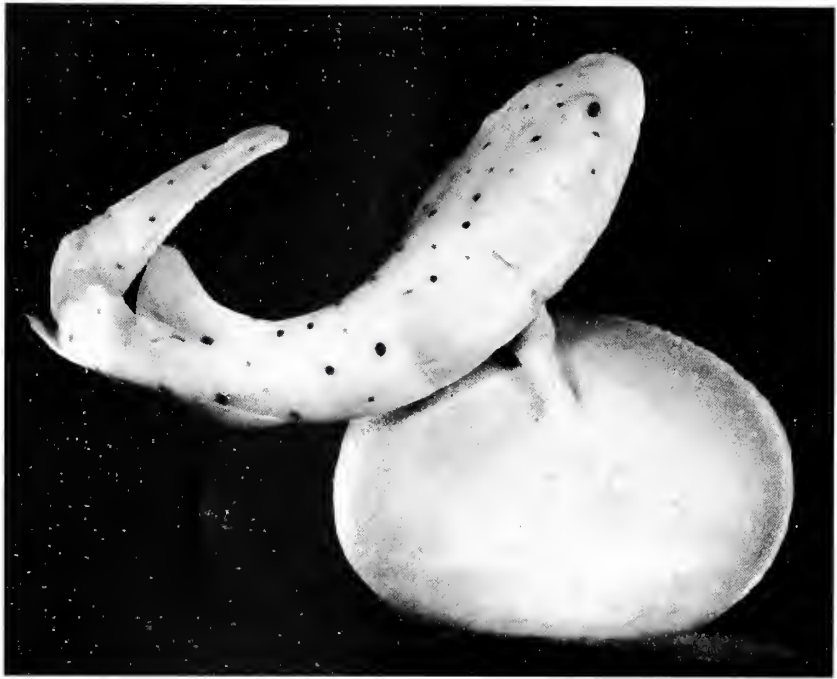


FIG. 3.

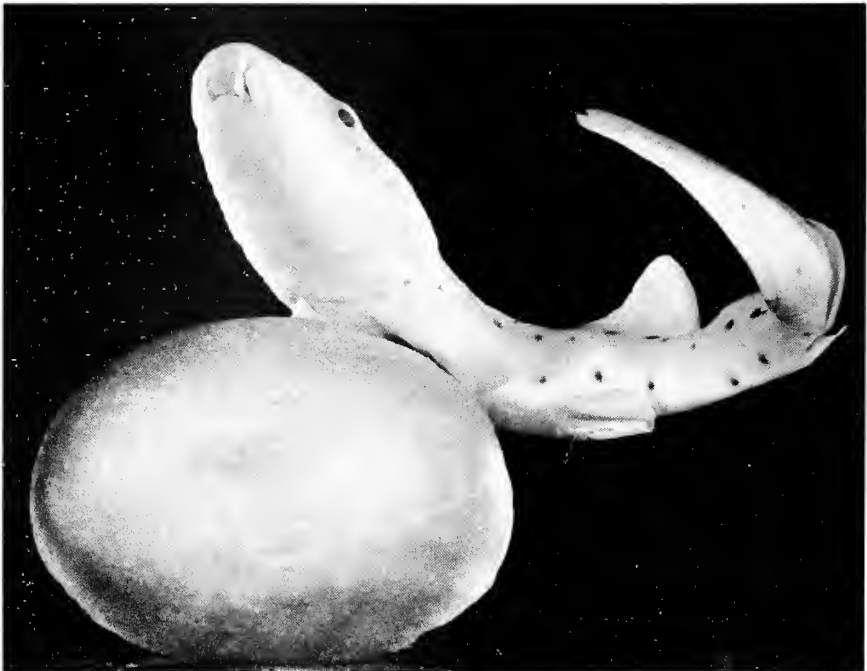


FIG. 4.

EXTERNAL CHARACTERS OF SIX EMBRYO NURSE SHARKS,
GINGLYMOSTOMA CIRRATUM (GMELIN).

5.

A Papillomatous Disease of the Gallbladder Associated with Infection by Flukes, Occurring in the Marine Turtle, *Chelonia mydas* (Linnaeus).¹

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and the New York Aquarium

&

C. W. COATES & R. F. NIGRELLI
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(Plates I-IV; Text-figure 1).

In two earlier publications attention was called to certain cutaneous tumors occurring in the turtle *Chelonia mydas* (Linnaeus) (Smith & Coates, 1938, 1939). These growths, fibro-epithelial in character, are found distributed on the neck and in the axillary, inguinal, eyelid, conjunctival and corneal regions. As a rule the tumors have the morphological characteristics of benign growths; rarely does the structure suggest a malignant change. In the majority of such tumors ova of a blood fluke can be demonstrated on microscopical study, giving rise to the hypothesis that blood flukes or ova may act as causative factors in the production of these lesions. In earlier studies ova occurring in cutaneous tumors were identified as those coming from *Hapalotrema constrictum* (Leared). Recent studies of a number of these worms (Nigrelli, 1940), however, indicate that this blood fluke is the same as *Distomum constrictum* of Leared (1862) and the form described by Price (1934) as *Learedius learedius*. The form described as *Hapalotrema constrictum* (Leared) Looss, 1899 (= *Mesogonimus constrictum* Monticelli, 1896) is now designated as *Hapalotrema mistroides* (Monticelli). This form is also a blood fluke but found in another species of marine turtle *Caretta caretta* (Linnaeus) (= *Thalassochelys caretta* (Linnaeus)). It must be pointed out here, however, that the original identification was tentative and based on the shape and size of the eggs, which are strikingly similar. Relationships and identifications of worms have been based on egg characteristics by various taxonomists.

Further studies of lesions in turtles as a result of fluke infections, carried on during the past year, have revealed a new form of papillomatous disease of the gallbladder of *Chelonia mydas*

which may be the result of a fluke infection of this organ.

A brief description of the gallbladder lesions and of the fluke itself follows.

Infected gallbladders show a wide range of lesions, depending doubtless upon the intensity and duration of the infection and the susceptibility of the tissues of the host. Any part of the fundus of the gallbladder may show thickened papillomatous change in solitary patches (Plate I, Fig. 1; Plate II, Fig. 4) or in confluent irregular masses (Plate I, Fig. 2). A papillomatous hyperplasia of the mucous membrane near the cystic duct's entrance into the gallbladder may be the most conspicuous lesion, the result of infection by trematodes (Plate II, Figs. 4, 5, 6). In consequence, the cystic end of the gallbladder may appear greatly thickened and encroaching on the lumen of the gallbladder (Plate IV, Fig. 12) almost to the point of producing a stenosis or obstruction. At times the entire wall of the gallbladder participates in the lesion. In these circumstances the epithelium is thrown up into papillomatous folds (Plate III, Figs. 7, 8), the muscularis shows increased amounts of connective tissue and lymphoid cell infiltration and the subserosa may be oedematous, thickened, and contain a large number of dilated capillaries both vascular and lymphatic. All sorts of irregularly dilated glands are formed in the hyperplastic epithelium. Often glands penetrate down into the submucosa. However, malignant invasive changes have not been noted to date in approximately one hundred gallbladders examined which have shown the effects of fluke infection. Malignant change might readily be expected as a result of these chronic hyperplastic changes. In order to determine whether or not the papillomatous lesions do become malignant it will be necessary to have

¹ Aided by a grant from the Marine Cancer Fund of Yale University School of Medicine.

access to more extensive material than is available at the present time.

The majority of the flukes lie free in the dark green, thickened, often inspissated bile of the infected gallbladder. Flukes often are attached to the papillomatous parts of the mucous membrane (Plate IV, Fig. 11). The parasites may lie partly buried in the mucosa (Plate I, Figs. 1, 2). There can be little doubt that the presence of flukes at the site of characteristic lesions of the mucous membrane indicates that the underlying cause of the disease arises in mechanical or chemical factors related to the activities of the infecting flukes. Ova surrounded by epithelioid or even giant cells may be found in the mucous membrane or other parts of the walls of the gallbladder (Plate III, Fig. 9). Mucous production is abundant (Plate III, Fig. 10).

The parasites from the gallbladder of *Chelonia mydas* have been identified as *Rhytidodoides similis* Price, 1939. A related species *R. intestinalis* was described in the same paper. According to Price, the identifications of "Both *R. intestinalis* and *R. similis* are in each case based on only two specimens; consequently it is not possible to determine the amount of variation within the species." A collection of large numbers of the gallbladder form has afforded an opportunity to make just such a study for this species, at least (Text-figure 1).

The worms are lanceolate in shape, tapering at both ends of the body and broadening considerably in the middle region. The posterior tip of the body can be extended into a minute "tail-like" appendage. When the flukes are examined in profile there is a characteristic hump on the dorsal side. In contracted specimens, the hump is more pronounced than in the extended forms. On the ventral surface, the acetabulum is prominent and immediately anterior to this sucker may be seen the genital ridge and pore.

The flukes are transparent and stained with bile. They measure $1.2 \times .42$ - 4.4×1.8 mm., with an average size of $2.2 \times .97$ mm. for fifty specimens. Cuticula without spines, smooth in expanded worms, with minute folds in contracted specimens. Oral sucker subterminal, measuring 140.2-342 microns in diameter (average, 293.4 microns), with lateral projections. The projections are prominent in the smaller individuals, less so in larger forms but are nevertheless a constant feature. Acetabulum, 170.3-385.6 microns (average, 300.7 microns), pre-equatorial. Pre-pharynx lacking; pharynx 80-179 \times 50-170 microns; esophagus of variable length, depending entirely on the state of contraction and expansion of the worms. Intestinal ceca simple, extending to the posterior extremity of the body. Excretory pore subterminal, dorsal; excretory vesicle Y-shaped, branching immediately behind the posterior testis, with the arms extending as far anterior as the pharynx. Genital aperture median, anterior to the ventral sucker and in the region of the cecal bifurcation. Cirrus pouch elongate piriform, muscular, situated over or

slightly in front of the acetabulum, measuring 150-700 microns \times 150-456 microns (average measurement 152×478.8 microns). Seminal vesicle and *pars prostatica* present. Testes in posterior third of the body, placed one behind the other or slightly oblique to the axis of the body, sometimes globular, sometimes sub-globular or ovoid in shape. Anterior testis usually smaller, measuring 102-420 microns \times 250-456 microns; posterior testis 152-532 microns in diameter. In very small forms testes and vitellaria are poorly developed. Ovary globular, 91-280 microns in diameter (average, 250 microns), sub-median and pre-testicular in position. Ovarian complex, consisting of Mehlis' gland, seminal receptacle, vitelline reservoir, and Laurer's canal. Vitellaria consist of four groups of more or less elongated follicles; two small groups of follicles are in the anterior region of the body and present as two distinct masses, one on each side of the esophagus between the acetabulum and pharynx; the two larger groups extend from the acetabulum to the posterior extremity of the body. Main vitelline ducts pass medially into the ovarian complex at about the level of the posterior border of the ovary. Uterus fills the entire intercecal space between the ovary and acetabulum; metraterm present. Eggs yellowish, thick-shelled, embryonated, measuring on the average 36×72 microns.

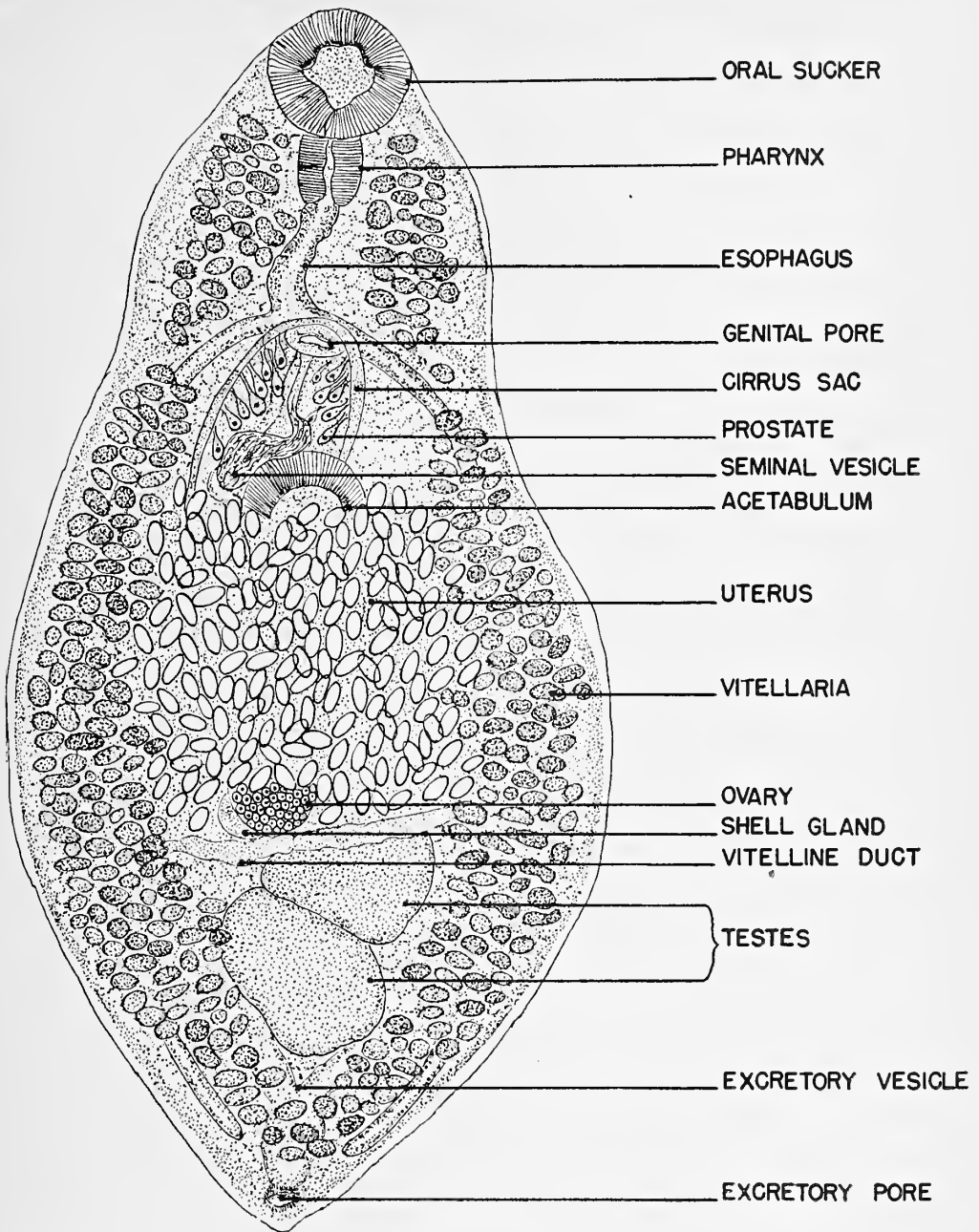
COMMENT.

The histo-pathology of trematode infections among lower vertebrates is not well known. The condition reported above is in many respects not unlike liver fluke infections in mammals (see Craig & Faust, 1940).

In sheep liver fluke, *Fasciola hepatica* Linnaeus, larvae are ingested with contaminated vegetation. Excystment takes place in the duodenum where the parasites penetrate the wall and pass into the body cavity. They continue their migration, passing through the liver capsule directly into the liver substance. The mechanical irritation produced, in the case of heavier infections, results in necrosis and fibrosis of the liver. Such an infection in man may cause cystic enlargement of the ducts, adenomata of the biliary epithelium, leucocytic and eosinophilic infiltration, and eventually the development of scar tissue. Often, in their wanderings through the liver substance, the worms produce abscesses, and the mechanical damage causes atrophy of the liver and the portal vessels.

Local lesions of this kind may be produced by other liver flukes such as the lancet fluke, *Dicrocoelium dentriticum* (Rudolphi), the cat liver fluke, *Opisthorchis felineus* (Rivolta), and the Chinese liver fluke, *Clonorchis sinensis* (Cobbold).

In dicrocoeliiasis, sheep and other herbivorous mammals become infected by eating grass and other vegetation containing encysted larvae. When eaten, such larval forms excyst in the duodenum and find their way to the biliary passages, often producing hypertrophy of the



Text-figure 1.

Rhytidodoides similis Price. $\times 54$.

epithelium. Both opisthorchiasis and clonorchiasis infections are brought about by eating fish poorly cooked, improperly cured, or raw, harboring the encysted stage.

In clonorchiasis, the larvae, following excystment, make their way up the common bile duct and migrate to the distal bile capillaries. Lesions produced by such infections have been described by Faust & Khaw (1927), Høeppli (1933) and

others. These include the proliferation of biliary epithelium, crypt formation in the bile duct, periepithelial fibrosis, periportal connective tissue hyperplasia and fibrous development around masses of eggs infiltrated in the liver substance.

Although the papillomatous disease of the gallbladder of *Chelonia mydas* is stressed in the present contribution, there are also definite responses in the liver and biliary ducts of these

animals which will be discussed in a subsequent report.

SUMMARY.

1. Gallbladders of the marine turtle *Chelonia mydas* (Linnaeus) were found heavily infected with a fluke referred to as *Rhytidodoides similis* Price, 1939.

2. These flukes produce certain pathological changes in the tissues of the gallbladder. The outstanding feature of these lesions is a papillomatous hyperplasia of the mucous membrane.

3. The parasites inducing these lesions are redescribed.

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EXPLANATION OF THE PLATES.

PLATE I.

- Fig. 1. Strip of gallbladder mucous membrane showing to the right a small papilloma with several flukes attached to or partly buried in the mass.
- Fig. 2. Photograph of inside of gallbladder attached to the liver. Note confluent masses of papillomatous tissue; flukes lie attached or partly buried in the growth.

PLATE II.

- Fig. 3. Section of normal gallbladder containing bile.
- Fig. 4. Thickened, shrunken, infected gallbladder with several small papillomata near the entrance of the cystic duct.
- Figs. 5-6. Small contracted gallbladders infected by fluke, *Rhytidodoides similis*. The great thickening of the mucosa and submucosa has occurred near the cystic duct.

PLATE III.

- Figs. 7-8. Irregular hyperplasia of papillomatous regions of infected gallbladders. $\times 35$.

- Fig. 9. Photo-micrograph of papillomatous region of gallbladder showing fragments of ova at points a and b. Epithelioid cells surround the small fragment at b. $\times 120$.
- Fig. 10. Masses of mucous formed at the surface of papilloma. $\times 100$.

PLATE IV.

- Fig. 11. Microscopic section of trematode *Rhytidodoides* attached to the hyperplastic epithelium of the gallbladder. Section of the parasite is at the level of the ventral sucker and the cirrus sac. $\times 40$.
- Fig. 12. Photo-micrograph of the cystic end of infected gallbladder. The hyperplastic mucous membrane is thrown into countless folds which encroach upon the lumen of the gallbladder. Submucosa and muscularis are thickened. The subserosa seen in the upper part of the photograph is oedematous and contains numerous blood and lymphatic vessels. $\times 25$.

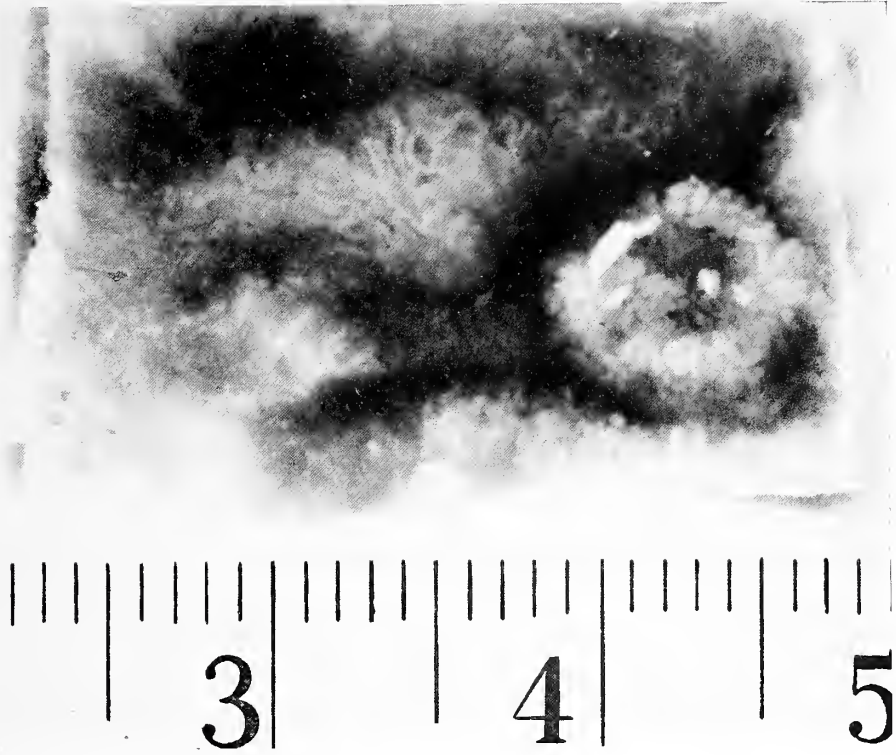


FIG. 1.

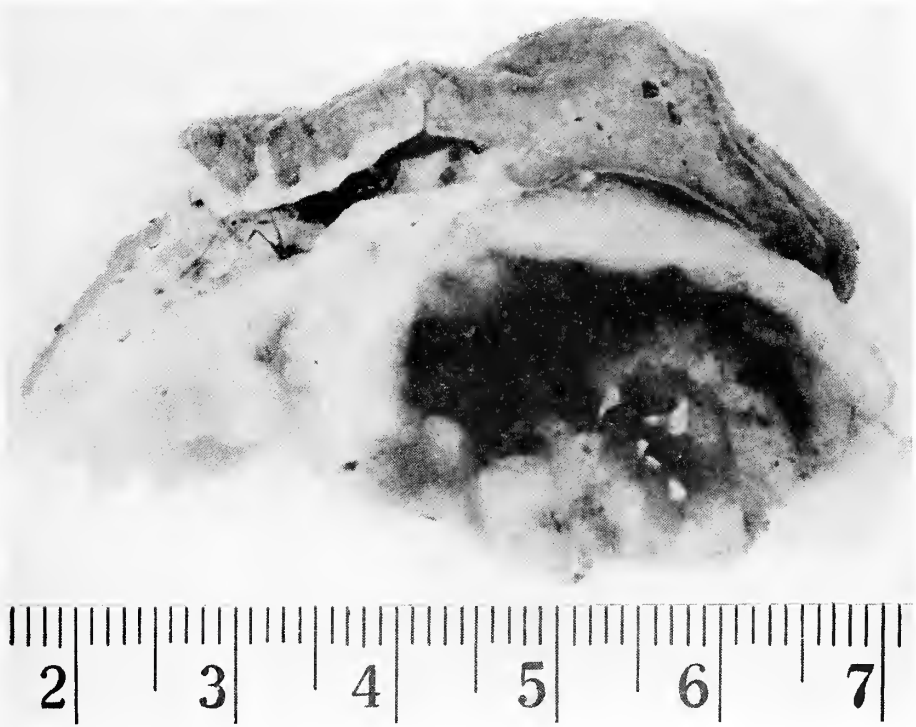


FIG. 2.

A PAPILOMATOUS DISEASE OF THE GALLBLADDER ASSOCIATED WITH INFECTION BY FLUKES, OCCURRING IN THE MARINE TURTLE, CHELONIA MYDAS (LINNAEUS).

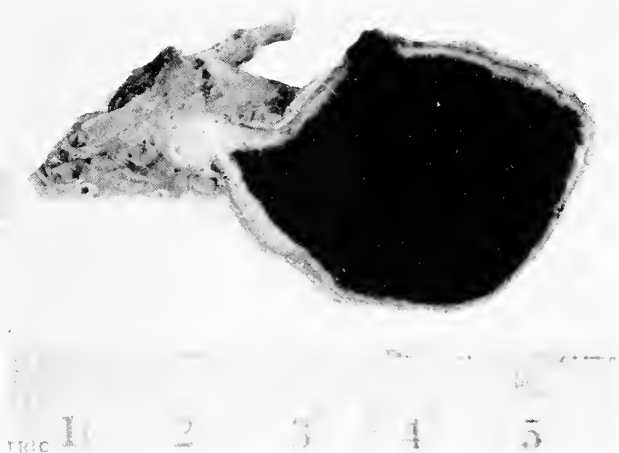


FIG. 3.

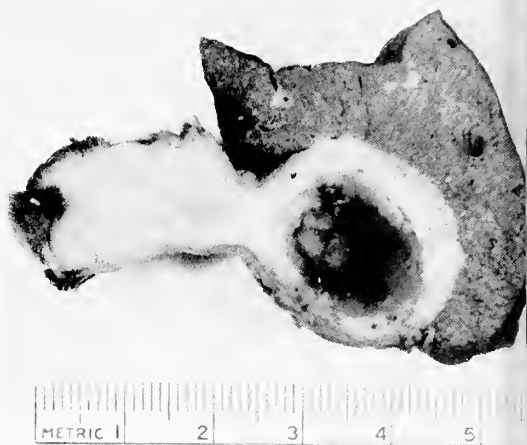


FIG. 4.



FIG. 5.

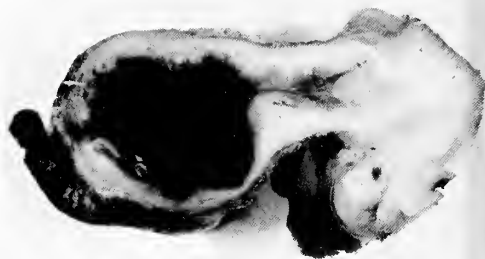


FIG. 6.

A PAPILOMATOUS DISEASE OF THE GALLBLADDER ASSOCIATED WITH INFECTION BY FLUKES, OCCURRING IN THE MARINE TURTLE, *CHELONIA MYDAS* (LINNAEUS).

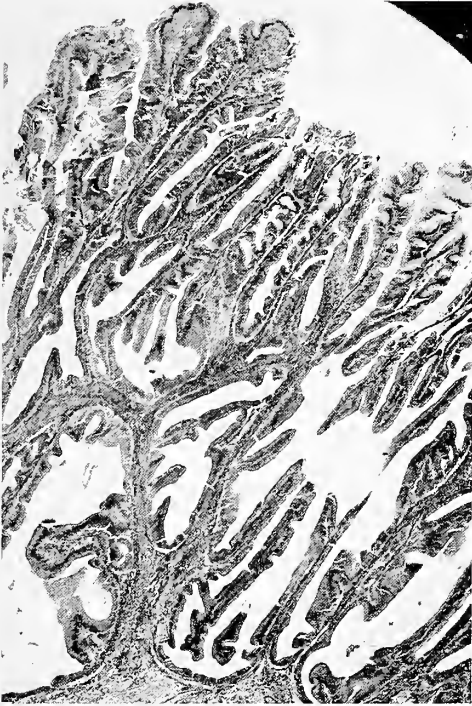


FIG. 7.



FIG. 8.



FIG. 9.



FIG. 10.

A PAPILLOMATOUS DISEASE OF THE GALLBLADDER ASSOCIATED WITH INFECTION BY FLUKES, OCCURRING IN THE MARINE TURTLE, *CHELONIA MYDAS* (LINNAEUS).

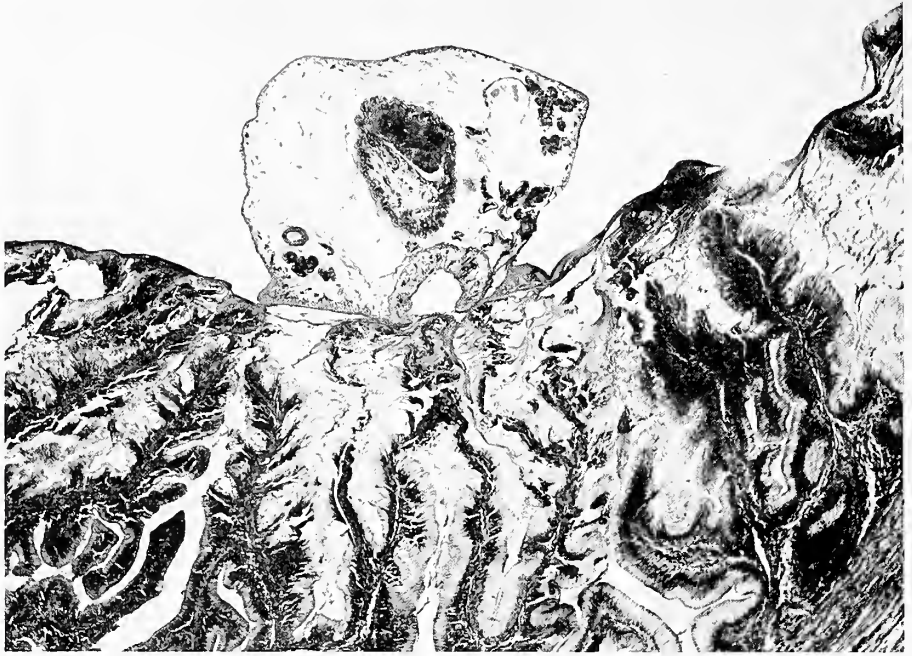


FIG. 11.

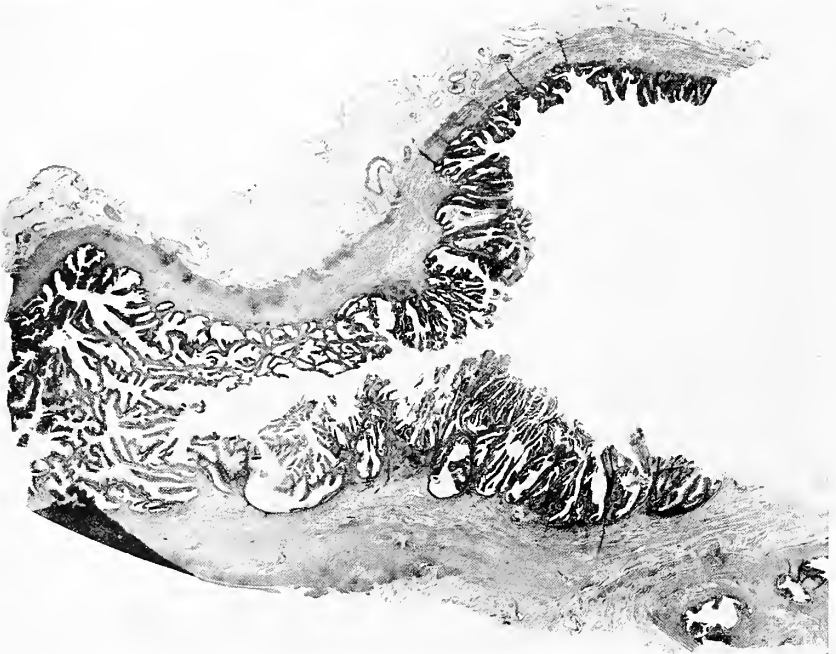


FIG. 12.

A PAPILLOMATOUS DISEASE OF THE GALLBLADDER ASSOCIATED WITH INFECTION BY FLUKES, OCCURRING IN THE MARINE TURTLE, *CHELONIA MYDAS* (LINNAEUS).

6.

**Eastern Pacific Expeditions of the New York
Zoological Society. XXIII.
Polychaetous Annelids from the West Coast of
Mexico and Central America.¹**

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Department of Zoology, Vassar College

(Text-figures 1-21).

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[This is the twenty-third of a series of papers dealing with the collections of the Eastern Pacific Expeditions of the New York Zoological Society made under the direction of Dr. William Beebe. The present paper is concerned with specimens taken on the Eastern Pacific *Zaca* (1937-1938) Expedition, which was made possible through the generosity of Mr. Templeton Crocker. For data on localities, dates, dredges, etc., refer to *Zoologica*, Vol. XXIII, No. 14, pp. 287-298.]

INTRODUCTION.

The following is a taxonomic account of 30 species of polychaetous annelids collected by Dr. William Beebe on the Eastern Pacific *Zaca* Expedition in 1937-1938. Five new species are

included in the collection. They were collected from off Cedros Island, Lower California, on the north to Panama Bay on the south.

The catalogue numbers all refer to specimens in the collections of the Department of Tropical Research of the New York Zoological Society.

Systematic Account.

FAMILY AMPHINOMIDAE.

Hermodice Kinberg.

Hermodice carunculata Kinberg.

Hermodice carunculata Kinberg, 1857, p. 13.

Collected at Arriba Isthmus, Port Parker, Costa Rica, January 17, 1938, Cat. No. 3,882A.

¹ Contribution No. 613, Department of Tropical Research, New York Zoological Society.

Notopygos Grube.**Notopygos ornata** Grube.

Notopygos ornata Grube, 1856, p. 55.

Collected at Station 203: D-9 (Port Parker, Costa Rica, January 22, 1938, 2 fathoms), Cat. No. 381,093.

Chloeia Savigny.**Chloeia euglochis** Ehlers.

Chloeia euglochis Ehlers, 1887, pp. 18-24; pl. 1, figs. 1, 2; pl. 2, figs. 1-8; pl. 3, figs. 1-4.

Collected at Station 195: D-9 (Port Guatulco, Mexico, December 5, 1937, in 7 fathoms), Cat. No. 37,477. Collected at Port Guatulco, Mexico, December 5, 1937, in fish trap at 7 fathoms. Color plate Z-118, Cat. No. 37,429. Station 221: D-1 (Gulf of Chiriqui, Panama, March 13, 1938, 35 fathoms), Cat. No. 38,659.

Specimen 37,477. Dorsal surface iridescent purplish-gray with a wide blackish band down the middle of each side within which are numerous oblique yellow streaks. On the mid-dorsal line of each segment are a pair of longitudinal, slightly oblique yellow lines. Tentacles and dorsal cirri greenish-black; setae bright orange. Gills greenish-brown, with a central yellow band on each stem.

Eurythoe Kinberg.**Eurythoe complanata** Pallas.

Eurythoe complanata Pallas, Teste McIntosh. McIntosh, 1885 (as *E. pacifica* Kinberg), pp. 27, 28; pl. 2, figs. 3, 4; pl. 3, fig. 3; pl. 2A, fig. 13; pl. 3A, figs. 5-9.

Collected at Station 195: D-15 and D-16 (Port Guatulco, Mexico, December 6, 1937, in 1½ fathoms), Cat. No. 37,526. Sihuatanejo, Mexico, November 24, 1937, in coral, Cat. No. 37,266. Station 196: D-18 (Tangola-Tangola Bay, Mexico, December 13, 1937, 30 fathoms), Cat. No. 37,743. Abajo Rocks, Port Parker, Costa Rica, January 22, 1938, tide-pool, Cat. No. 381,094.

Eurythoe oculata sp. nov.

(Text-figures 1-3).

A single specimen. The body is broken and more or less macerated near its middle so that accurate measurements are impossible but it is approximately 180 mm. long. The greatest width, 10 mm., is at about the end of the anterior third of the body length. The prostomial width is 1 mm.

The prostomium (Text-fig. 1), is ovate with its broader end anterior, and has two pairs of prominent eyes. The anterior tentacles are slender and reach as far as to the anterior prostomial border. The median tentacle is relatively long, is attached at the level of the posterior eyes and extends to the anterior border of the anterior ones. The

tentacles are colorless, as is the prostomium. The caruncle is very small and inconspicuous and is attached to the dorsal border of the first somite (Text-fig. 1). This prostomium has certain resemblances to that of *E. dubia* Horst as redefined by Munro (1933, p. 5), but is longer in proportion to width than in his figure 1, the eyes are much more prominent and the tentacles more slender. Horst (1912, p. 37), and Munro describe the caruncle as flexuous though this is more clearly shown in Horst's figure than in Munro's. In *oculata* it is hardly more than a rounded papilla.

The parapodial lobes are widely separated. The dorsal cirrus is prominent and lies anterior to the tuft of gills. Two dorsal aciculae with rounded ends protrude to the surface at the base of the cirrus and three similar aciculae occur in the neuropodium (Text-fig. 2). The ventral cirrus is a rounded cone. The notosetae make up a dense tuft, are all alike, long, slender and sharp-pointed. Sometimes it is possible to see on the shafts the denticles figured by Horst (*loc. cit.*, pl. 10, fig. 7), but generally they seem smooth. I am uncertain what he meant by "dimples" on the shafts, and can find nothing that would answer to this description. The neurosetae (Text-fig. 3), are heavy, with apices bluntly rounded and an also bluntly rounded, subapical tooth.

The gills first appear on the third somite and when well developed consist of a tuft of 12 or more filaments arising from a common base just behind the insertion of the dorsal cirrus. A few filaments may be simple but most are at least 2-branched and some are irregularly dichotomously divided into as many as 6 branches.

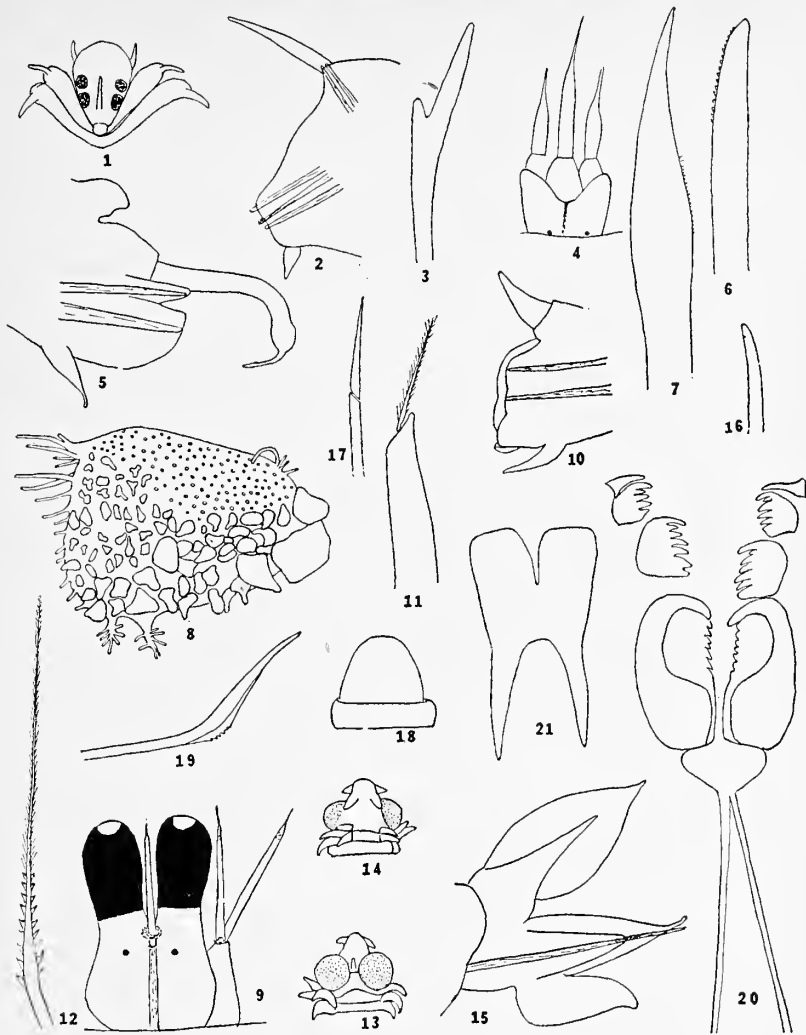
The type was collected at the dock in Balboa, Panama, July 25, 1933. It is a female with eggs, and is No. 3,319 in the collection of the Department of Tropical Research of the New York Zoological Society.

FAMILY POLYNOIDAE.

Lepidasthenia Malmgren.**Lepidasthenia picta** Treadwell.

Lepidasthenia picta Treadwell, 1928, pp. 456, 457; fig. 177; figs. 10-13.

A single specimen in this collection makes possible additions and corrections to the original diagnosis. The drawing (*loc. cit.*, fig. 10), shows a dividing line between the lateral prolongation of the prostomium and the cirrophore of the tentacle. This is incorrect. The cirrophore is a prolongation of the prostomium. In the type the palps and elytra were missing. In the *Zaca* material the former show as stout structures shorter than the median tentacle and having acuminate tips. The anterior elytra are approximately circular in outline and cover the tentacles which may be seen through them. The anterior dorsal margin of the elytron is faintly tinged with black and there is a small black spot ventral to the point of elytriphore attachment. Later elytra are more lateral in position, leaving a con-



Text-figures 1-21.

1-3. *Eurythoe oculata* sp. nov. 1, head $\times 7$; 2, parapodium $\times 6$; 3, neuroseta $\times 62$. 4-7. *Lepidasthenia elegans* sp. nov. 4, head $\times 12$; 5, parapodium $\times 20$; 6, notoseta $\times 180$; 7, neuroseta $\times 180$. 8, Elytron of *Eupholoe nuda* Treadwell $\times 25$. 9-12. *Polyodontes californicus* sp. nov. 9, head $\times 18$; 10, parapodium $\times 5$; 11, seta $\times 85$; 12, seta $\times 180$. 13-17. *Eulalia magnapupula* sp. nov. 13, dorsal surface of head $\times 10$; 14, ventral surface of head $\times 10$; 15, parapodium $\times 33$; 16, seta $\times 250$; 17, seta $\times 250$. 18-21. *Arabella pacifica* sp. nov. 18, head $\times 15$; 19, seta $\times 68$; 20, maxilla $\times 23$; 21, mandible $\times 23$.

siderable portion of the dorsum exposed. While anterior elytra are lightly pigmented, throughout the median and posterior regions the pigmentation is dense except for a colorless spot over the elytophore, this giving an ocellated appearance to the dorsal surface. The elytra have neither marginal fringes nor surface spines. The body coloration is somewhat different from that of the type, indicating some degree of variability.

Collected at Station 203: D-9 (Port Parker, Costa Rica, January 22, 1938, in $1\frac{1}{2}$ to 4 fathoms), Cat. No. 381,092.

Lepidasthenia elegans sp. nov.

(Text-figures 4-7).

Two specimens are in the collection, the type being incomplete. This is 25 mm. long and 10 mm. wide at the tenth somite. In the other, which is entire, the posterior region is badly preserved and it is impossible to determine the number of somites or of the elytra. The specimens are assigned to this genus subject to later correction. The prostomium (Text-fig. 4), is 1 mm. in diameter, is broader than long and has a

broad but not deep, anterior indentation into which fits the heavy cirrophore of the median tentacle. From the base of this indentation a dorsal groove runs posteriorly along the prostomial surface. The eyes are all near the posterior border, the posterior ones the smaller, nearer together and more or less covered by the margin of the first somite. The median cirrophore is heavy, its length rather more than half that of the prostomium. The style is about as long as the prostomium up to the point where it begins to taper and it has a slender terminal filament. Cirrophores of the lateral tentacles are short and stout, their styles shaped much like those of the median but only about two-thirds as long. The ventral tentacular cirrus is similar in form to the median tentacle, the dorsal one similar to the lateral tentacle but much more slender. The palps are slender and inconspicuous, hardly longer than the median tentacle. The first somite, carrying the elytraphore, is twice as wide as the prostomium, later ones increase in width up to the sixth.

The coloration is unlike in the two specimens, the type having five or six dark transverse bands on its dorsum in each somite, while the other has two irregular ones in this locality. Except for a slight tint near the apex of the palp there is no color in the head region.

The parapodium has a much reduced notopodium into which a stout acicula extends, the neuropodium is much heavier and rounded at the apex, anterior and posterior lobes equal (Text-fig. 5). The dorsal cirrus is on a heavy cirrophore whose diameter is more than half that of the parapodium, its style reaching considerably beyond the parapodium apex, slightly swollen near the end and terminating in a heavy filament. The ventral cirrus is very short, conical and has a slender tip. All but one of the notopodia examined had no setae, the exception having a single one. This was rather heavy, its apex bluntly rounded (Text-fig. 6), and it has transverse rows of teeth along one border, these being heavier than those in the neuropodium. There are about ten setae in the neuropodial group, these differing from one another mainly in size. They have rather heavy stalks which are swollen near the ends and then narrow to blunt points. Very small teeth, difficult to see unless the seta is in the proper position, occur along one margin of the swollen portion (Text-fig. 7).

The protruded pharynx is as long as the first seven somites. Dorsally and ventrally at its apex are marginal rows of nine papillae.

Anteriorly the elytra cover the dorsum. I am unable to say what the condition is in later somites. All elytra are circular in outline, the surface dotted with pigment spots and devoid of marginal filaments.

The specimens are recorded as commensal in a holothurian. They were collected at Station 126: D-14 (East of Cedros Island, Mexico in 45 fathoms), Cat. No. 3,773. The type is in the collection of the Department of Tropical Research of the New York Zoological Society.

Halosydna Kinberg.

Halosydna brevisetosa Kinberg.

Halosydna brevisetosa Kinberg, 1865, p. 85.

Collected at Station 126: D-19 (S. E. of Cedros Island, Mexico, November 10, 1937, in 25 fathoms), Cat. No. 3,794.

FAMILY SIGALIONIDAE.

Eupholoe McIntosh.

Eupholoe nuda Treadwell.

(Text-figure 8).

Eupholoe nuda Treadwell, 1936, pp. 53, 54; figs. 10-14.

As *Eupholoe nuda* I described a specimen from Bermuda in which I was uncertain whether all elytra had been lost or whether they had ever been present. The present collection contains one of this species with a full complement of elytra. They are decidedly lateral in position, leaving a considerable portion of the dorsum uncovered, and are essentially of the same form throughout the body. They, as well as the body surface, are covered with sand grains of which the largest on the elytra are those of the antero-dorsal area, some of which protrude beyond the elytral border (Text-fig. 8). The smallest of the grains are at the posterodorsal region where there are also some long marginal filaments. On the posteroventral face are two branched filaments and small ones occur on the remainder of the border except for a small part of the dorsal region where there are neither filaments nor sand grains. At this region the elytral surface is dotted with small spines.

My earlier material showed two kinds of compound setae (*loc. cit.*, figs. 13, 14), one much heavier than the other, the slender one with a subterminal tooth. The present material shows that the subterminal tooth is present on both kinds of setae but evidently is easily broken away. The setae differ, therefore, only in size.

Collected at Station 126: D-19 (S. E. of Cedros Island, Mexico, November 10, 1937, in 25 fathoms), Cat. No. 3,794.

Polyodontes californicus sp. nov.

(Text-figures 9-12).

The type and only specimen is a fragment, measuring 25 mm. to the region of the 20th elytron, and has a width of 10 mm. The prostomial diameter is about 1 mm., each half continued into an ommatophore, the base of each ommatophore being at about half way of the total prostomial-eye length, the apex of the eye being a trifle wider than the width of the stalk. There is a lens at the end. The sessile eyes are a pair of small dark spots, one on either side (Text-fig. 9). The base of the median tentacle is at the level of these sessile eyes and its stalk very slender, its apex narrowing to a filamentous tip which does not quite reach the apex of the ommatophore. At base of median tentacle is a ring of brownish pig-

ment and a median caruncle-like ridge runs posteriorly across the dorsal prostomial surface. The lateral tentacles are similar to the median in form and size but are not visible from the dorsal surface, being hidden beneath the ommatophores. Each has a pigmented ring at the base and another just proximal to the filamentous tip. The palps are slender, nearly three times as long as prostomium and ommatophores combined and are pigmented near the apices. The basal portion of the tentacular cirri extends as far as the base of the ommatophores, the styles slender, extending as far as the apex of the eyes, their apices abruptly ending in slender filaments. There is a band of brown pigment near the apex of the cirrophore and the dorsalmost cirrus has pigment near its apex and another pigmented mass near its base.

The protruded pharynx extends 10 mm. beyond the prostomium and at its apex is 7 mm. wide. The dorsalmost terminal papilla of the pharynx is 4 mm. long and on either side of it a row of 7 broad, flattened papillae with acute apices. The outermost one of each row is much the smallest and in most of them is a dark spot. The ventral median papilla is short, similar to, but a little larger than, the lateral ones of which there are 6 on either side. There are two light brown fangs with a single row of teeth on either side of each pair.

The protrusion of the pharynx produces enough distortion so that it is not possible to determine exactly the position of the anterior elytra. Evidently the first pair covers the prostomium and is colorless except for a few widely distributed black spots. The second is much smaller than the first, the third larger than the second but still smaller than the first. These have a few dark spots. The fourth is about as large as the third and diffusely pigmented. Beginning with the fifth, a considerable area of the dorsal surface is uncovered by elytra and these assume a very characteristic coloration and form. Each is approximately oval in outline, its long axis vertical and the outer end wider than the inner. Near the dorsal end is a densely pigmented band, separated by a colorless band from the elytron margin. From one-half to one-third of the elytron surface shows more or less pigmentation, the densest portion being the dorsal area mentioned above. The combined effect is that of two dark brown bands along the dorso-lateral surface of the body. A very faint brownish tint, due to numerous small transverse lines, marks the dorsal surface beneath the elytra. The remainder of the body is colorless. The first pair of ventral cirri are very large, following ones successively smaller, most reaching only to end of parapodium. The dorsal cirri are nearly of the same size throughout.

A median parapodium has nearly equal anterior and posterior setal lobes and a spoon-shaped lip underlying the neuropod (Text-fig. 10). The dorsal cirrus has a heavy cirrophore and a conical style reaching a short distance beyond the setal lobe. The ventral cirrus is much more slender, its acute tip just about reaching the end of the neuropod. There are three types of setae.

The first lie in the median portion of the row, have heavy brown shafts slightly enlarged and curved toward ends, apex obliquely truncated (Text-fig. 11). To this truncated portion is attached a slender terminal joint having fine hairs on its surface. Above and below these are slender setae, their apices very slender lanceolate in outline, the terminal portion covered by fine hairs. Another and larger tuft of colorless setae lies ventral to the heavy ones. These (Text-fig. 12) widen toward the ends and are curved. At the curve are toothed plates and beyond these, fine hairs cover the entire surface.

The gills are bladder-like structures on the dorsal parapodial surfaces and are most prominent on the elytra-bearing somites.

This species is here classed in the genus *Polyodontes*, because of the presence of gills. If, however, Chamberlin's synonymy is correct (1919, p. 86), *Polyodontes* is preoccupied and it should be listed as *Acoetes*.

The type was collected at Station 182: D-4 (Chamela Bay, Mexico, November 17, 1937, in 16 fathoms), Cat. No. 37,152, and is in the collection of the Department of Tropical Research of the New York Zoological Society.

FAMILY APHRODITIDAE.

Aphrodita Linnaeus.

Specimens of *Aphrodita*, all too badly preserved to admit of species identification, were collected at Station 189: D-2 (17 miles S. E. by E. of Acapulco, Mexico, November 29, 1937, in 20 fathoms), Cat. No. 37,742; Station 195: D-17 (Port Guatulco, Mexico, December 7, 1937, in 6 fathoms), Cat. No. 37,741; Station 214: D-3 and 4 (14 miles S. by E. of Judas Point, Costa Rica, March 1, 1938, in 50 and 61 fathoms), Cat. No. 38,409.

FAMILY PHYLLODOCIDAE.

Phyllodoce Savigny.

Phyllodoce oculata Ehlers.

Phyllodoce oculata Ehlers, 1887, pp. 135-140; pl. 40, figs. 4-6.

Collected at Station 220: L-2 (Isla Parida, Gulf of Chiriqui, Panama, March 12, 1938, surface light), Cat. No. 38,650; Station 126: D-19 (S. E. of Cedros Island, Mexico, November 10, 1937, in 25 fathoms), Cat. No. 3,794.

Phyllodoce groenlandica Oersted.

Phyllodoce groenlandica Oersted, 1842-43. Teste McIntosh. McIntosh, 1908-10, pp. 86-88; pl. 58, fig. 5; pl. 68, figs. 4-6; pl. 78, fig. 7.

Collected at Station 223: L-1 (Bahia Hermosa, Coiba Island, Panama, March 19, 1938, at surface light), Cat. No. 38,760.

Eulalia magnapupula sp. nov.

(Text-figures 13-17).

Characterized by very large eyes and short

tentacles and cirri. Two specimens, of which the type is the larger but is incomplete. The smaller is 57 mm. long and in the anterior body region is 4 mm. in diameter to the ends of the setae. The posterior end is very narrow and possibly regenerating.

In the preserved material the anterior margin of the prostomium is rounded, the lateral margins straight and running directly into the eyes (Text-fig. 13). The paired tentacles are heavy cones hardly longer than wide, only the anterior ones visible from the dorsal surface. The median tentacle is inconspicuous and is situated at about the middle of the dorsal prostomial surface. The eyes are very large, either one being larger than the exposed portion of the prostomium. Their lenses are visible only from the sides. The tentacular cirri are one pair on the first somite, two pairs on the second and one pair on the third (Text-fig. 14). The cirrophores of dorsal one on second and third pairs are heavy and about as long as the styles. The style of the third pair is the longest but this barely reaches the third somite. The eyes are dark brown, the peristomial surface is marked by brown pigment, cirrophores of tentacular cirri dark brown, styles colorless. Anteriorly the body color is light brown with a tendency toward a transverse dark band near the anterior margin of the somite and a darker spot on the anterior margin of the parapodium. This latter spot becomes more prominent posteriorly, and posterior to about the twenty-fifth somite is carried on a definite rounded lobe. The flattened dorsal cirri are more or less spotted with brown. Anteriorly on the ventral surface the pigmentation is diffuse, while posteriorly there is a dark spot at the base of each parapodium. On the midventral portion of each somite is an uncolored spot shaped like a thickened H which is prominent against the diffuse brown of the general surface. Neither specimen retains the anal cirri.

The parapodium is conical (Text-fig. 15), the posterior lip the longer and terminating in a filamentous tip, the acicula protruding from the surface by the side of this filament. Between the two lips arises a fan-shaped seta tuft. The dorsal cirrus is broad-lanceolate on a heavy cirrophore and reaches about as far as the end of the filament on the setal lobe. The ventral cirrus is shorter than the setal lobe, heavy, with recurved tip. There are two kinds of setae, the first simple, bluntly rounded and slightly curved at the tip (Text-fig. 16), the other compound, with a long basal joint, the terminal joint slender and sharp-pointed (Text-fig. 17).

In the type the pharynx is protruded to a distance equal (in preserved material), to the length of the first eight somites.

The type was collected at Station 225: T-1 (11 miles S. W. by S. of Jicaron Island, Panama, March 20, 1938, in 500 fathoms), Cat. No. 38,767. Another specimen was taken at Station 227: T-1 (20 miles S. W. of Morro de Puercos, Panama, March 21, 1938, in 500 fathoms), Cat. No. 38,789. The type is No. 38,767 in the collection of the

Department of Tropical Research of the New York Zoological Society.

FAMILY TOMOPTERIDAE.

Tomopteris Eschscholtz.

Tomopteris opaca Treadwell.

Tomopteris opaca Treadwell, 1928, pp. 463, 464, fig. 178; fig. 29.

Collected at Station 210: T-10 (20 miles south of Cape Blanco, Costa Rica, February 27, 1938, in 500 fathoms), Cat. No. 38,391. Station 233: T-1 (55 miles south of Cape Corrientes, Colombia, April 3, 1938, in 500 fathoms), Cat. No. 38,908.

FAMILY TYPHOSCOLECIDAE.

Travisiopsis Levinsen.

Travisiopsis atlantica Treadwell.

Travisiopsis atlantica Treadwell, 1936, pp. 62, 63; figs. 30-33.

Collected at Station 227: T-1 (20 miles S. W. of Morro de Puercos, Panama, March 21, 1938, in 500 fathoms), Cat. No. 38,789.

FAMILY LEODICIDAE.

Leodice Savigny.

Leodice longisetis Webster.

Leodice (Eunice) longisetis Webster, 1884, pp. 317, 318; pl. 10, figs. 46-49.

Collected at Sihuatenajo, Mexico, November 24, 1937, in coral, Cat. No. 37,266.

Leodice paloloides Moore.

Leodice paloloides Moore, (?) 1919, pp. 246-249; pl. 7, figs. 5-7.

Collected at Sihuatenajo, Mexico, November 24, 1937, in coral, Cat. No. 37,266A.

Diopatra Aud. et M. Ed.

Diopatra ornata Moore.

Diopatra ornata Moore, 1911, pp. 273-277; pl. 18, figs. 77-85.

Collected at Station 196: D-18 (Tangola-Tangola Bay, Mexico, December 13, 1937, in 30 fathoms), Cat. No. 37,645A.

Hyalinoecia Malmgren.

Hyalinoecia juvenalis Moore.

Hyalinoecia juvenalis Moore, 1911, pp. 277-280; pl. 18, figs. 86-95.

Collected at Station 203: D-2 (Port Parker, Costa Rica, January 20, 1938, in 10 fathoms), Cat. No. 38,109A.

Arabella Grube.**Arabella pacifica** sp. nov.

(Text-figures 18-21).

The body is broken about at its middle but the entire animal is preserved, the total length being 160 mm. The body width is 3 mm., the prostomial width 1.3 mm. The prostomium is rounded (Text-fig. 18) and no eyes are visible. The anterior parapodia are very small, later ones increase in size but the posterior ones are small. There are two anal cirri, these being short with rounded ends. On the parapodia are prominent dorsal lobes extending to the ends of the setae. Setae are of only one kind (Text-fig. 19), having slender stalks widened and geniculate toward the extremities with very sharp apices and a pair of toothed wings at the bend. In profile only one of the wings is visible and unless slightly tilted the marginal denticulations do not appear. In each parapodium are three aciculae protruding only very slightly from the surface.

All mouth parts jet black. In the maxilla the terminal plate on either side has only one tooth (Text-fig. 20). No. 2 has on either side a 6-toothed plate; No. 3 on either side 7 teeth. The forceps are heavy and overlie the proximal plates so that without destroying the specimen it was not possible to determine the precise number of teeth in each of the latter, but they extend as far as the forceps base and are toothed for the greater part of their length. Apparently also the inner margin of the forceps is toothed. The basal rods are very long, less than half of them being shown in the figure. The mandible is rectangular with a forked base (Text-fig. 21).

The type was collected at Sihuatanejo, Mexico, November 24, 1937, in coral, Cat. No. 37,266, and is in the collection of the Department of Tropical Research of the New York Zoological Society.

FAMILY AMPHICTENIDAE.

Pectinaria Lamarck.**Pectinaria gouldii** Verrill.

Pectinaria gouldii Verrill, 1873, p. 612; figs 87, 87A.

Collected off Ballenas Bay, Gulf of Nicoya, Costa Rica, February 26, 1938, in mangrove mud, Cat. No. 38,359A.

FAMILY OPHELIIDAE.

Ammotrypane Rathke.**Ammotrypane bermudiensis** Treadwell.

Ammotrypane bermudiensis Treadwell, 1936, pp. 60, 61; figs. 24-26.

Collected at Station 208: D-3 (Piedra Blanca Bay, Costa Rica, February 5, 1938, in 4 fathoms), Cat. No. 38,187A.

FAMILY CAPITELLIDAE.

Notomastus Sars.

A single specimen of undetermined species was collected at Station 126: D-16 (East of Cedros Island, Mexico, November 10, 1937, 42 fathoms), Cat. No. 3,781.

FAMILY GLYCERIDAE.

Hemipodus Quatrefages.**Hemipodus mexicanus** Chamberlin.

Hemipodus mexicanus Chamberlin, 1919, pp. 349-350; pl. 63, figs. 2-3.

Collected at Station 126: D-16 (East of Cedros Island, Mexico, November 10, 1937, in 42 fathoms), Cat. No. 3,781A.

FAMILY CHLORHAEMIDAE.

Stylarioides Della Chiaje.**Stylarioides** sp.?

Collected at Station 221: D-5 (Gulf of Chiriqui, Panama, March 13, 1938, in 35-40 fathoms), Cat. No. 38,659A.

FAMILY TERESELLIDAE.

Terebella Linnaeus.**Terebella gorgonae** Munro.

Terebella gorgonae Munro, 1933 A, pp. 1070, 1071, fig. 18.

Collected at Station 203: D-9 (Port Parker, Costa Rica, January 22, 1938, in 2 fathoms), Cat. No. 38,111.

Terebellides Sars.**Terebellides stroemi** Sars.

Terebellides stroemi Sars, 1835. Teste McIntosh. McIntosh, 1922, pp. 209-215; pl. 120, fig. 3; pl. 127, fig. 5.

Collected at Station 126: D-16 (East of Cedros Island, Mexico, November 10, 1937, in 42 fathoms), Cat. No. 3,781A.

A single specimen of an empty tube of a terebellid, strongly resembling that of *Lanice* figured by McIntosh (1885, pl. 49, fig. 4), was collected at Station 224: D-3 (Hannibal Bank, Panama, March 20, 1938, in 35 fathoms), Cat. No. 38,755.

FAMILY SABELLIDAE.

Sabella Linnaeus.**Sabella melanostigma** Schmarda.

Sabella melanostigma Schmarda, 1861, p. 36. Ehlers, 1887, p. 263.

Collected at Sihuatanejo, Mexico, March 24, 1937, in coral, Cat. No. 37,266A.

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7.

Plankton of the Bermuda Oceanographic Expeditions. X.
 Polychaetous Annelids from Bermuda Plankton, with
 Eight Shore Species, and Four from Haiti.¹

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(Text-figures 1-9).

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[This is the tenth of a series of papers dealing with the plankton content of a series of nets drawn through a cylinder of water off the coast of Bermuda on the Bermuda Oceanographic Expeditions of the Department of Tropical Research under the direction of Dr. William Beebe. Full details as to this circle of water, and of the dates, depths, etc., of the nets will be found in *Zoologica*, Vol. XIII, Nos. 1, 2 and 3, pp. 1-45, and *Zoologica*, Vol. XXI, No. 3, pp. 69-73.]

INTRODUCTION.

The following is an account of 23 species of polychaetous annelids collected primarily at Bermuda on the Bermuda Oceanographic Ex-

peditions of the Department of Tropical Research of the New York Zoological Society, plus materials relating to specimens collected on the Haitian Expedition of the Department in 1927. Three new species are described, the types of which are deposited in the collections of the Department of Tropical Research.

Systematic Account.

FAMILY AMPHINOMIDAE.

Hermodice Kinberg.*Hermodice carunculata* Kinberg.

Hermodice carunculata Kinberg, 1857, p. 13.

Collected at Cooper's Island, Bermuda, in mud, Sept. 11, 1931, Cat. No. 312,029. Nonsuch Island, Bermuda in shallow water, July 23, 1929, Cat. No. 29,135.

¹Contribution No. 614, Department of Tropical Research, New York Zoological Society.

Contribution from the Bermuda Biological Station for Research, Inc.

FAMILY POLYNOIDAE.

Lepidonotus Leach.*Lepidonotus pilosus* Treadwell.

Lepidonotus pilosus Treadwell, 1937, pp. 141-143, pl. 1, figs. 1-7.

Collected at Bizoton, Port-au-Prince Bay, Haiti, March 22, 1927.

FAMILY SIGALIONIDAE.

Acanthicolepis Norman.*Acanthicolepis longicirrata* sp. nov.

(Text-figures 1-4).

Characterized by the long tentacles and cirri and by the large eyes. As seen from above the pigmented borders of the two eyes on either side are in contact (Text-fig. 1) and appear to run together, forming a heavy pigmented border to the prostomium. The lens of the posterior eye points laterally, thus seeming to bend the pigmented band toward the dorsal surface. The lens of the anterior eye is not visible from above.

Length 15 mm., width of prostomium 1 mm., greatest body width to parapodial bases 4 mm. in region of 9th somite. At first gradually, later more rapidly, the body tapers to about 0.5 mm. at the posterior end. Only one elytron remains and the preservation is such that it is impossible to be certain of the elytriphore count in later somites but the number is apparently 18. The prostomium is somewhat broader than long, each half ending on its anterior margin in a well marked peak. The cirrophore of the median tentacle is heavy, set into a shallow depression between the two prostomial halves. The style of the median tentacle is about the length of the palps, these 3 mm. long, colorless and curved, the apices diverging. Cirrophores of the lateral tentacles small, styles slender, reaching to about the middle of the palps. Only one tentacular cirrus and one dorsal cirrus remain, these being about as long as the palps. Each cirrus has a central opaque white core, the remainder being translucent. Apparently the elytra originally covered the dorsal surface but only one remains. This is so transparent as to be easily overlooked. On its surface are numerous, evenly distributed, low spines visible under a 40 diameter magnification. Its outline is approximately circular.

In a parapodium taken from in front of the middle of the body (Text-fig. 2) the notopodium is shorter than the neuropodium and the latter when seen from above has an inflated appearance, its longitudinal diameter being greater than that of the notopodium. The notopodial acicula is shorter but slightly heavier than the neuropodial, the former being covered nearly to its apex by a symmetrical tissue outgrowth. A similar outgrowth covers the neuroacicula but there is in addition a papilla lying parallel to the acicula end (Text-fig. 2). The ventral cirrus is slender and elongated, extending for nearly half its length beyond the apex of the setal lobe. The

notosetae are heavier than the neurosetae and form a diverging tuft which extends almost vertically from the notopodium. They are of two kinds, one straight and sometimes very heavy, the others shorter and curved. Both have transverse rows of plates whose margins seem not to be particularly toothed. The neurosetae are more numerous and more slender. The dorsal ones in the tuft are slender, have very sharp points and alternately arranged rows of toothed plates (detail in Text-fig. 3). Ventral to these are fewer and larger ones which enlarge toward the ends and then narrow to acute apices. A row of toothed plates lies along one margin of the tapered portion (Text-fig. 4).

The type was collected in Net 1,503, 600 fathoms deep, off Bermuda, July 25, 1934. Others were taken in Net 1,316, 800 fathoms, off Bermuda, Sept. 17, 1931, Cat. No. 312,135. It was also taken at Station 114: T-5, 500 fathoms, in the Hudson Gorge, 125 miles off New York City, July 8, 1928. The type is No. 3,465 in the collection of the Department of Tropical Research of the New York Zoological Society.

FAMILY PHYLLODOCIDAE.

Eulalia Savigny.*Eulalia megalops* Verrill.

Eulalia megalops Verrill, 1900, p. 601.

Collected in Castle Harbor, Bermuda, August 13, 1931, Cat. No. 311,247. Taken in a bivalve shell in coral.

Mystides Theel.*Mystides gracilis* sp. nov.

(Text-figures 5-7).

A slender species represented only by an incomplete specimen. What remains is 62 mm. long and about 1.5 mm. in diameter in greatest width. The prostomium (Text-fig. 5) has the form of a cone with rounded apex, the sides nearly straight lines. The eyes are large and have prominent lenses. Behind the prostomial margin is a small tubercle. The tentacles are about one-third as long as the prostomium. There are four pairs of tentacular cirri arranged according to the generic formula. The third pair are the longest, reaching somite 7; the dorsal of the second pair reaches to somite 5. Except for faint transverse lines on the anterior dorsum, the body is colorless. In most of the anterior region the dorsal cirri have been lost but those that remain are very small, barely reaching to the end of the setal lobes. Posterior ones (Text-fig. 6) are much larger, are rectangular in form and carried on heavy bases. In the setal lobe there is a slightly bifid posterior lip and a rounded one coming to the surface between them. In each parapodium there are about ten setae having rather heavy basal joints, enlarged and spiny at the ends. The terminal joints are long and slender, curved, and toothed on the concave margins (Text-fig. 7). The ventral cirri are longer than the setal lobe, have ovate outlines and acute apices.

FAMILY ALCIOPIDAE.

Vanadis Claparède.*Vanadis fuscipunctata* Treadwell.

Vanadis fuscipunctata Treadwell, 1906, pp. 1159-1160, figs. 29-31.

Collected in Bermuda in the following: Net 10, 400 fathoms, April 9, 1929, Cat. No. 2932; Net 1,175, 600 fathoms, Aug. 14, 1931, Cat. No. 311,761, color transparent, eyes scarlet; Net 1,262, 700 fathoms, Sept. 4, 1931, Cat. No. 311,807; Net 1,264, 900 fathoms, Sept. 4, 1931, Cat. No. 311,821, color dirty tan in general, eyes coral red; Net 1,275, 1,000 fathoms, Sept. 7, 1931, Cat. No. 311,866, color white, eyes scarlet; Net 1,308, 100 fathoms, Sept. 16, 1931, Cat. No. 312,073, color olive, eyes red; Net 1,321, 50 fathoms, Sept. 18, 1931, Cat. No. 312,167, color lemon yellow, eyes coral red; Net 1,508, 100 fathoms, Aug. 14, 1934, Cat. No. 34,256.

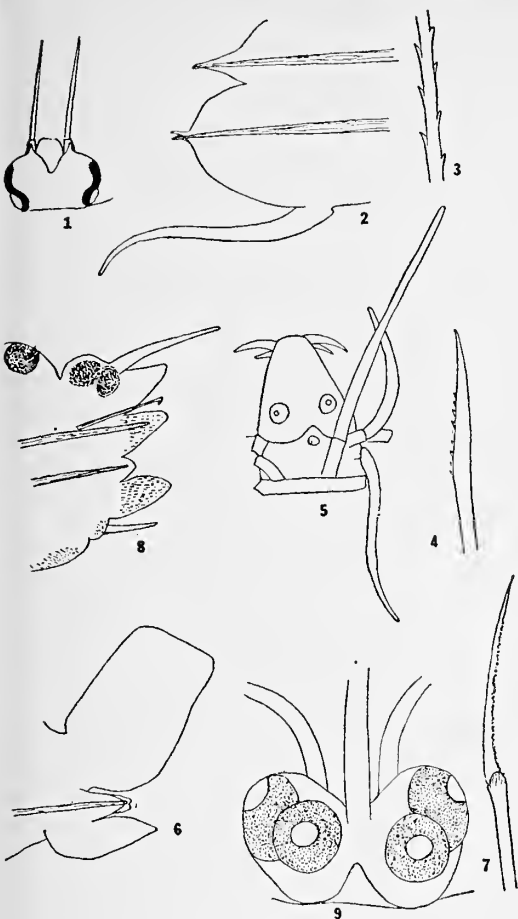
The following field-notes were made upon specimen No. 31,472 (Net 1,050, 25 fathoms, July 6, 1931), 23 mm. long:

Color: Eyes coral red with gleaming, brighter centers which are at the base of a tiny projecting crystal dome. Otherwise the animal is entirely transparent except for a yellowish, reddish, brownish or blackish spot behind the base of each lateral appendage. These spots are lightest and brightest when the worm is active or when it has been exposed for some time to bright light. There is no noticeable change in their size, except possibly a slight contraction after the worm was placed in the darkness of a refrigerator. The eyes paled only slightly when the worm was kept in darkness. As the worm weakened a growing opaqueness was noticeable.

Movements: Locomotion is principally by means of the short, three-leaved, shamrock-like paired appendages which, on alternate sides, are thrown abruptly forward and back so that the worm, seen from above, has a ridiculous sort of waddle. It seems to move either ahead or in reverse with equal facility and no apparent change of method. When greatly excited it shoots through the water with tremendous contortions, twistings and loopings of the entire body.

The partitions between the segments, as transparent as the body wall, are pierced by holes which, more or less rhythmically, though not in unison, expand almost to full diameter of the segment and contract nearly to pinheads. The funnel-shaped proboscis is likewise contractile.

This worm remained alive in the Bermuda laboratory for two days. It was kept in a quiescent condition in the refrigerator most of the time, but was revived at intervals of a few hours in the warm air of the laboratory. About five to ten minutes were required for it to show signs of life.



Text-figures 1-9.

1-4. *Acanthicolepis longicirrata* sp. nov. 1, head $\times 12$; 2, parapodium $\times 23$; 3, detail of stalk of neuroseta $\times 180$; 4, neuroseta $\times 85$. 5-7. *Mystides gracilis* sp. nov. 5, head $\times 15$; 6, parapodium $\times 33$; 7, seta $\times 250$. 8, *Nereis agassizi* Ehlers. Parapodium $\times 23$. 9, *Autolytus bidens* sp. nov. Head $\times 45$.

The type was collected in Net 1,179, off Bermuda at the surface, August 14, 1931, Cat. No. 311,288, and is in the collection of the Department of Tropical Research of the New York Zoological Society.

Lopadorhynchus Grube.*Lopadorhynchus uncinatus* Fauvel.

Lopadorhynchus uncinatus Fauvel, 1916, pp. 57-61, pl. 1, figs. 2-3; pl. 4, figs. 4-14.

Collected in Bermuda in the following nets: Net 1,321, 50 fathoms, Sept. 18, 1931, Cat. No. 312,166, color, pinkish tan; Net 1,337, 600 fathoms, Oct. 29, 1931, color orange.

FAMILY TOMOPTERIDAE.

Tomopteris Eschscholtz.*Tomopteris longisetis* Treadwell.

Tomopteris longisetis Treadwell, 1936, pp. 58-59, figs. 18-21.

Collected in Bermuda, Net 1,332, 600 fathoms, Oct. 28, 1931, Cat. No. 312,227, color white.

Fragments and young of tomopterids were collected in other nets at Bermuda, but none were identifiable.

FAMILY TYPHOSCOLECIDAE.

Travisiopsis Levinsen.*Travisiopsis atlantica* Treadwell.

Travisiopsis atlantica Treadwell, 1936, pp. 62, 63, figs. 30-33.

Collected in Bermuda in the following nets: Net 793, 700 fathoms, July 9, 1930, Cat. No. 30,477; Net 869, 1,000 fathoms, Sept. 10, 1930, Cat. No. 30,844, color orange yellow; Net 881, 600 fathoms, Sept. 12, 1930, Cat. No. 30,904, color orange yellow; Net 956, 1,000 fathoms, Sept. 28, 1930, Cat. No. 301,307; Net 1,258, 900 fathoms, Sept. 3, 1931, Cat. No. 311,778; Net 1,264, 900 fathoms, Sept. 4, 1931, Cat. No. 311,820, color transparent white.

FAMILY NEREIDAE.

Nereis Cuvier.*Nereis bairdii* Webster.

Nereis bairdii Webster, 1884, pp. 312-313, pl. 8, figs. 22-28.

Collected at the surface at Bermuda as follows: Net 982, surface, May 19, 1931, Cat. No. 3,124; Net 1,179, surface, Aug. 14, 1931, Cat. No. 311,286; dip net at night-light, Aug. 27, 1937. Those from Net 982 are in the heteronereis stage.

Nereis mirabilis Kinberg.

Nereis mirabilis Kinberg 1865, p. 170.

Collected in Bermuda as follows: Net 982, surface, May 19, 1931, Cat. No. 3,124A; Net 1,332, 600 fathoms, Oct. 28, 1931, Cat. No. 312,286.

Nereis agassizi Ehlers.

(Text-figure 8).

Nereis agassizi Ehlers, 1868, pp. 542-546, pl. 23, fig. 1.

A single specimen, doubtfully identified as this species. Its most characteristic features are the dark parapodial glands and the single heavy spine in each parapodium lying almost in contact with the notopodial acicula on its dorsal surface (Text-fig. 8). This also conforms with reasonable accuracy to the brief description of *N. kubiensis* as given by McIntosh (1885, pp. 210-212, pl. 34, figs. 3-6; pl. 16a, figs. 2-4). I was unable to get

a good view of the jaw apparatus which would have been confirmatory. Both of these species have some resemblances to *N. dumerilii* Aud. et M. Ed., but no diagnoses that I have seen of the latter species mention the heavy spine.

Collected in Bermuda, Net 1,237, 700 fathoms, Aug. 29, 1931, Cat. No. 311,651, color orange-yellow.

FAMILY LEODICIDAE.

Leodice Savigny.*Leodice stigmatura* Verrill.

Leodice stigmatura Verrill, 1900, pp. 641-643.

Collected in tidepool on Nonsuch Island, Bermuda, April 23, 1929, Cat. No. 2,945.

Leodice culebra Treadwell.

Leodice (Eunice) culebra Treadwell, 1901, p. 197, fig. 37.

Dredged off Nonsuch Island, Bermuda, 2 fathoms, Nov. 4, 1931, Cat. No. 312,339.

Leodice mutilata Webster.

Leodice (Eunice) mutilata Webster, 1884, pp. 315-316, pl. 9, figs. 36-40.

Collected in coral, Castle Harbor, Bermuda, May 1929.

FAMILY SYLLIDAE.

Autolytus Grube.*Autolytus bidens* sp. nov.

(Text-figure 9).

In a bottle labeled "luminous worms, from Castle Harbor, Bermuda" were numerous fragments of an *Autolytus* that is evidently of a new species. No entire individuals were present and I have no information concerning absolute size or differences in body regions. The prostomium (Text-fig. 9), is broader than long, its posterior margin deeply indented and almost its entire dorsal surface taken up by the eyes of which the anterior pair is the larger. They are dark brown in color and very conspicuous. The median tentacle is from six to eight times as long as the prostomium, lateral tentacles much shorter and a little more slender. Tentacular cirri about as long as the median tentacle. The first few dorsal cirri are long, later ones shorter but all longer than body width. Width of prostomium about 2/3 mm. The pharynx extends through six somites, the brown oesophagus through two, the stomach through seven. In the type the first twenty-one somites have only compound setae while later ones have in addition a tuft of long and extremely slender simple ones. With the appearance of the longer setae the antero-postero diameter of the parapodia increases, giving them a swollen appearance. There was no indication of sex products.

The compound setae are very small, the basal joint slightly widened and beveled at the end.

The terminal joint is extremely short and has a terminal tooth and a smaller one at about the middle of the concave surface.

Collected at surface, Nonsuch Island, Bermuda, Nov. 16, 1931. Type, No. 312,351, Department of Tropical Research, New York Zoological Society.

Haplosyllis Langerhans.

Haplosyllis gula Treadwell.

Haplosyllis gula Treadwell, 1924, pp. 11, 12, figs. 19-23.

Dredged in shallow water, Isle de Gonave, Haiti, June 1, 1927, Cat. No. 272.

FAMILY AMPHICTENIDAE.

Pectinaria Lamarek.

Pectinaria gouldii Verrill.

Pectinaria gouldii Verrill, 1873, p. 612, figs. 87, 87a.

Collected in Castle Harbor, Bermuda, Nov. 2, 1931, 2 fathoms, Cat. No. 312,342.

FAMILY OPHELIIDAE.

Ammotrypane Rathke.

Ammotrypane bermudiensis Treadwell.

Ammotrypane bermudiensis Treadwell, 1936, pp. 60, 61, figs. 24-26.

Collected at surface off Nonsuch Island, Bermuda, May 12, 1931, Cat. No. 317. Specimens dredged at 2 fathoms, off Nonsuch Island, Bermuda, Aug. 25, 1931, Cat. No. 311,675, and Oct. 3, 1931, Cat. No. 312,234.

FAMILY GLYCERIDAE.

Telake Chamberlin.

Telake epipolasis Chamberlin.

Telake epipolasis Chamberlin, 1919, pp. 346-348, pl. 63, figs. 4-8; pl. 64, fig. 1.

Collected at Bermuda, Net 1,179, surface, Aug. 14, 1931, Cat. No. 311,287.

FAMILY TERESELLIDAE.

Eupolymnia Verrill.

Eupolymnia magnifica Webster.

Eupolymnia (Terebella) magnifica Webster, 1884, p. 324, pl. 11, figs. 58-60.

Collected in Bermuda as follows: Nonsuch Island, tidepools, Apr. 23, 1929, Cat. No. 2,945A; Nonsuch Island, tidepools, Aug. 22, 1929, Cat. No. 29,158; surface at night, near Nonsuch Island, Sept. 13, 1931, Cat. No. 311,996.

FAMILY SABELLIDAE.

Dasychonopsis Bush.

Dasychonopsis conspersa Ehlers.

Dasychonopsis (Dasychone) conspersa Ehlers, 1887, pp. 226-270, pl. 54, figs 1-6.

From bottom of old barge, Bizoton, Port-au-Prince Bay, Haiti, Cat. No. 27,212.

FAMILY SERPULIDAE.

Spirobranchus Blainville.

Spirobranchus tricornis (Mörch) Ehlers.

Spirobranchus tricornis Ehlers, 1887, pp. 292-295; pl. 57, figs. 8-15.

Collected at Lamentin Reef, Port-au-Prince Bay, Haiti, Apr. 26, 1927, Cat. Nos. 27,379, 27,385, color red with golden setae.

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8.

Caudal Skeleton of Bermuda Shallow Water Fishes. V. Order Percomorphi: Carangidae.¹

GLORIA HOLLISTER

Department of Tropical Research

(Text-figures 1-20).

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INTRODUCTION.

This is the fifth of a series of papers dealing with the caudal skeleton of Bermuda fishes. The Carangidae of Bermuda is represented by six genera and twelve species. No specimens are available of *Caranx guara*, considered uncommon in Bermuda, either in the collection of this department or in the collections of several other institutions. *Caranx guara*, locally known as "Gwelly," is seen by fishermen in shallow water but is said to be a shy, wary fish.

This paper deals principally with the adult fishes, as is the case with the four preceding studies of this series, but when young stages were available these were included.

The length of specimens in this paper is standard length unless otherwise stated.

For caudal fin terminology, general bibliography, and method of preparing specimens for this study, refer to Part I.

The symbols used in the figures are EP, epural; HS, haemal spine; 1, 2, 3, 4, 5, hypurals; IHS, interhaemal spine; INS, interneural spine; NS, neural spine; UN, uroneural; UR, urostyle.

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Contribution from the Bermuda Biological Station for Research, Inc.

We are indebted to the American Museum of Natural History for three specimens of *Argyreiosus vomer*. I take this opportunity to thank Dr. William Beebe, Director of this Department, and Mr. John Tee-Van, General Associate, for their cooperation.

The drawings are by Miss Janet B. Wilson, who kindly volunteered to do this work.

In Bermuda Carangidae several precaudal vertebrae are neither typical trunk nor typical caudal in structure. In all species these vertebrae have ribs (although in several specimens diminutive), which is characteristic of the typical trunk vertebrae. Closed haemal arches are also present, a typically caudal character. These precaudals include several modified vertebrae which immediately precede the true caudal.

The structure of the precaudal haemal arch in *Trachurops* differs radically from that of *Chloroscombrus* and *Caranx* and is readily distinguished from these two latter species by the crescent-shaped arch.

In *Decapturus macarellus* and *Decapterus punctatus* several precaudals and anterior true caudals are crescent-shaped and arise on the anterior half of their centra. *Decapturus* is the only species in this study which has the anterior true caudal haemal processes crescent-shaped.

It is of interest to note that the Bermuda Synodontidae is also unlike the families studied in Parts I, II and IV in having several vertebrae in the precaudal region which deviate from the typical trunk and caudal forms. In Synodontidae there are present, between the trunk and caudal, vertebrae lacking ribs (ribs being characteristic of the trunk), and also lacking closed haemal arches with spines, this structure being characteristic of the caudal.

In Bermuda Carangidae there is also this deviation from what is generally designated typical trunk and typical caudal vertebrae. This difference is found in several precaudal haemals which

have closed arches typical of the caudal region but lack the haemal spine which is typical of the trunk. Because of these differences the term precaudal centra is used as in Synodontidae.

The key is based on characters of the adult. In this respect it is important to mention, as an example, that in the immature specimen of *Chloroscombrus chrysurus*, 6 mm., the difference in length of the three short posterior neural and haemal spines and the length of the preceding long pair of spines is not pronounced as it is in the adult. In the mature specimen both the difference in length and shape is conspicuous and is considered a key character.

1. *Decapterus macarellus* (Cuvier & Valenciennes).

(Text-figure 7).

Diagnostic Characters:

1 interneural and 1 interhaemal arising over the 4th vertebra anterior to the urostyle.

The horizontal length of this posterior interneural and interhaemal about one and a half times longer than the anterior oblique part.

Haemal base of first anterior caudal lunar-shaped.

Caudal interneurals and interhaemals more slender than in the other genera.

Third stout posterior neural and haemal spines dagger-shaped and extend obliquely over three quarters of the following vertebra.

Material Studied.

The following description is taken from one specimen caught in Bermuda, Cat. No. 9,139, KOH Cat. No. 604, length 140 mm.

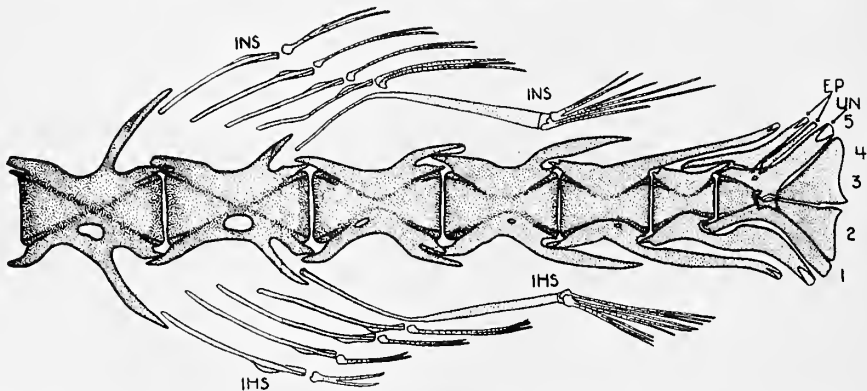
Caudal Osteology.

Urostyle: The urostyle is conical in shape. The posterior end appears to be consolidated on the dorsal surface with the base of the uroneurals and the fifth hypural and on the ventral with part of

the base of the first and second hypurals. The anterior part of the urostyle is identical in form and size with the adjacent posterior part of the penultimate centrum.

Uroneurals: There is one pair of uroneurals. These paired bones extend from the anterior margin of the urostyle to the distal margin of the hypural complex. On dissecting away the caudal rays the dorsal tip appears distinct from the tip end of the fifth hypural with which the uroneurals are fused. Text-figure 9 of a 10 mm. *Decapterus punctatus* shows the small fifth hypural in relation to the undeveloped uroneurals. Both these bones are only slightly ossified. Where young specimens of Carangidae were available for study this same relation of the two bones is found. Text-figures 13, 16, 17 and 18.

Hypurals: In this adult specimen there appear to be four hypural bones; two below and two above the median line. In the 10 mm. *Decapterus punctatus*, Text-figure 9, the large dorsal hypural is divided almost to the distal margin, indicating that in a slightly younger specimen this single bone of the adult is formed by two separate elements. This condition is found in several other young carangids. Text-figures 16, 17. The first and fifth hypurals are almost identical in size and are complimentary in their distal positions in the marginal complex. The two large median hypurals of the adult are completely separate to the anterior rounded ends which are partly covered by the base of the uroneurals and the projected lateral muscle attachment process of the first hypural. The fifth or dorsal-most hypural is recognized in the adult by the pointed tip adjacent to the end of the fourth hypural. For its entire length, with the exception of this tip, the fifth hypural is fused with the uroneurals, and appears as one with these bones. Younger specimens give the true explanation of the development and relationship of the fifth hypural and the uroneurals. In the 42 mm. specimen of *Decapterus punctatus* the fifth hypural is more easily distinguished by the prominent line of junction which is still present between the hypural and the uroneurals.



Text-figure 7.

Decapterus macarellus. Tail of 140 mm. specimen showing especially the prolonged posterior interneural and interhaemal spines. $\times 3.52$.

Epurals: There are two epurals. The posterior bone is slender and rod-like and slants obliquely forward and downward from the distal caudal margin to the dorsal edge of the uroneurals. The ventral tip is inserted between the two lateral uroneural bones. The anterior epural is wider than the ventral epural throughout the entire length. Anteriorly, a long finger-like projection extends forward and fills the area above the reduced neural process of the last centrum. Similar to the smaller epural, part of the ventral tip is inserted between the uroneural bones.

Additional Characters Worthy of Note: This is the only genus of Bermuda Carangidae which has the extremely long and slender posterior interneural and interhaemal spines. The anterior and median ends arise near the anterior zygapophyses of the fourth vertebra from the urostyle and the bones extend back and toward the centra almost to the posterior margin of the next centrum. The interneurals and interhaemals, preceding the prolonged posterior pair, are more slender than in the other species studied in this paper.

The precaudal haemal processes and also the first caudal haemals are lunar-shaped and placed on the anterior part of the centra. This development is similar to *Decapterus punctatus*.

2. *Decapterus punctatus* (Agassiz).

(Text-figures 8, 9).

Diagnostic Characters:

2 interneurals and 2 interhaemals arising over the 4th vertebra anterior to the urostyle.

The horizontal length of this posterior pair only a little longer than the anterior oblique part.

Haemal base of first anterior caudal lunar-shaped.

Caudal interneurals and interhaemals not as slender as those of *Decapterus macarellus*.

Dorsal and ventral fin rays not as slender as those of *Decapterus macarellus*.

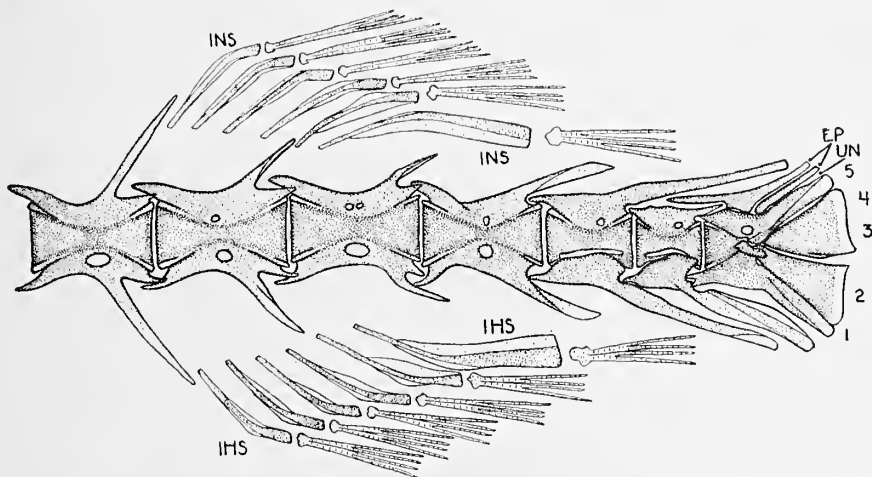
Material Studied.

The following description is taken from three specimens caught in Bermuda, Cat. No. 8,968, KOH Cat. No. 2316, length 10 mm.; KOH Cat. No. 340, length 18 mm.—taken from under a jellyfish; KOH Cat. No. 2315, length 42 mm.

Caudal Osteology.

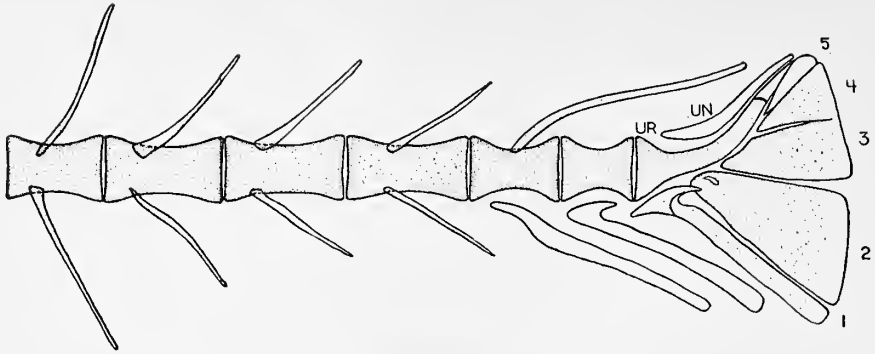
Urostyle: In the 42 mm. specimen the urostyle is conical in shape and similar to *Decapterus macarellus*. No definite posterior tip can be seen. In the 10 mm. specimen the upturned posterior end of the urostyle extends beyond the basal end of the fifth hypural. The anterior margin is identical in form with that of the preceding centrum but posteriorly the shape changes radically into a long slender upturned structure. The urostyle is slightly ossified as far as the base of the fifth hypural. Here, there is a heavy line across the urostyle and beyond this there is little ossification.

Uroneurals: As in *Decapterus macarellus*, there is a single pair of uroneurals and in the 42 mm. specimen these paired bones are similar in shape and position to those of the above species. In *Decapterus punctatus* the line of junction between the fifth hypural and the uroneurals is distinct but this has disappeared in the older specimen of the other species. In the 10 mm. *Decapterus punctatus* the uroneurals are long, slender, curved bones which extend from the hypural margin to the anterior part of the urostyle. Throughout their entire length the uroneurals are separate from the urostyle and the fifth hypural.



Text-figure 8.

Decapterus punctatus. Tail of 42 mm. specimen showing the difference between this species and *Decapterus macarellus* in the arrangement and proportions of the interneural and interhaemal spines of the posterior groups. $\times 9.65$.



Text-figure 9.

Decapterus punctatus. Tail of 10 mm. specimen. This stage shows the development of the 3rd and 4th hypurals which are fused in the 42 mm. specimen. The fifth hypural and the uro-neurals are separate bones in this stage. $\times 45.4$.

Hypurals: In the 42 mm. specimen there appears to be four hypurals; two below and two above the median line. In the 10 mm. specimen there are three hypural bones above the median line, which indicates that the large dorsal hypural of mature specimens is a combination of two bones. Also this young specimen has a small slit in the base of the second hypural which probably indicates a one-time ancestral division of this other large hypural bone. In all Bermuda *Isospondyli* and *Iniomis* there are at least three hypurals below the median line. In general shape and proportions the hypural complex of the adult *Decapterus punctatus* resembles that of *Decapterus macarellus*, with the exception of the identity of the fifth hypural and uroneurals.

Epurals: There are two epurals in the adult, as in *Decapterus macarellus*, and the shape and proportions are similar. In this species the ventral ends are not inserted between the uroneural bones, but this may be an age character. There is no trace of the epurals in the 10 mm. specimen.

Additional Characters Worthy of Note: The posterior pair of interneural and interhaemal spines are conspicuously longer than the preceding spines and the oblique part extends posteriorly for almost the length of the following centrum. This pair is not as long nor as slender as the corresponding pair of *Decapterus macarellus*. The precaudal haemal processes and also the first caudal haemals are lunar-shaped and placed on the anterior part of the centra.

In the 10 mm. specimen the caudal centra are only moderately spool-shaped and the zygapophyses and the neural and haemal processes are undeveloped. The neural and haemal processes are simple, slender bones and there is little differentiation in the development of the four anterior pair of spines. This difference is conspicuous in the adult.

3. *Trachinotus palometa* Regan.

(Text-figure 10).

Diagnostic Characters:

1 long and slender interneural and 1 interhaemal arising over the 4th vertebra anterior to the urostyle.

17 interneurals in the caudal region.

Bases of haemal processes arising at the center of the centra.

No short or stout posterior neural and haemal spines.

Material Studied.

The following description is taken from one specimen caught in Bermuda, KOH Cat. No. 601, length 119 mm.

Caudal Osteology.

Urostyle: The anterior part of the urostyle is identical in size and shape to the adjacent part of the preceding penultimate centrum. The posterior end cannot be seen because it is consolidated with the bases of the uroneurals and hypurals. The dorsal surface is covered by the uroneurals and the ventral surface by the hypural bases.

Uroneurals: There appears to be a single pair of uroneurals, the bones of which extend from the anterior dorsal edge of the urostyle to the distal margin of the hypurals. For part of the distal length the line of junction between the fifth hypural and the uroneurals is distinct. In the smaller specimen of *Trachinotus goodei* these bones appear separate.

Hypurals: In this adult specimen there appear to be four hypural bones; two below and two above the median line. The second large hypural below the median line is solid with the exception

of a small oblong hole near the base. In *Trachinotus goodei* of 54 mm. in length, the base is divided and a definite line can be seen which extends for half the length of the hypural bone. In the large dorsal hypural of *Trachinotus palometa* there is also indication that this hypural was at one time divided because a distinct line extends anteriorly from the distal margin for more than three-quarters of the length of the hypural. In the other species the base of this large dorsal hypural is divided and a narrow slit extends for about one-quarter the length of the bone and does not quite join with the slit extending from the distal margin. In the species under discussion the fifth or dorsal-most hypural is closely associated with the uroneurals but each can be identified at their dorsal extremity by distinct and separate pointed tips and a line which extends anteriorly for almost half the length. From here the two are fused. In the other species this fifth hypural is more distinct. Hypural numbers have been omitted from this illustration because of the inclusion of the caudal fin rays; for hypural reference, see Text-figure 11 of *Trachinotus goodei*.

Epurals: There are three epurals in this species and genus. The anterior or first epural is the largest, which is true of the adults of all the other species treated in this paper. Anteriorly, there is a broad thin growth which almost fills the entire area dorsal to the penultimate centrum and the urostyle. The second and third epurals are long, slender bones and very closely associated.

At both the proximal and distal ends the tips can be distinguished as separate bones. The ventral ends are not inserted between the uroneurals as is the case in *Trachinotus goodei*. Often this appears as a growth character but the specimen of this species is less than half the size of *Trachinotus palometa* and the tips of the former are inserted.

Additional Characters Worthy of Note: The illustration of this species is the only one which includes the caudal fin rays because the variation in the count is slight in the other species of Carangidae and therefore of little importance. Here the count is: dorsal raylets 6 plus 11 dorsal rays, and ventral raylets 6 plus 9 ventral rays, making a total of 17 dorsal plus 15 ventral.

4. *Trachinotus goodei* Jordan & Evermann.

(Text-figure 11).

Diagnostic Characters:

2 broad interneural and interhaemal spines arising over the 5th vertebra anterior to the urostyle.

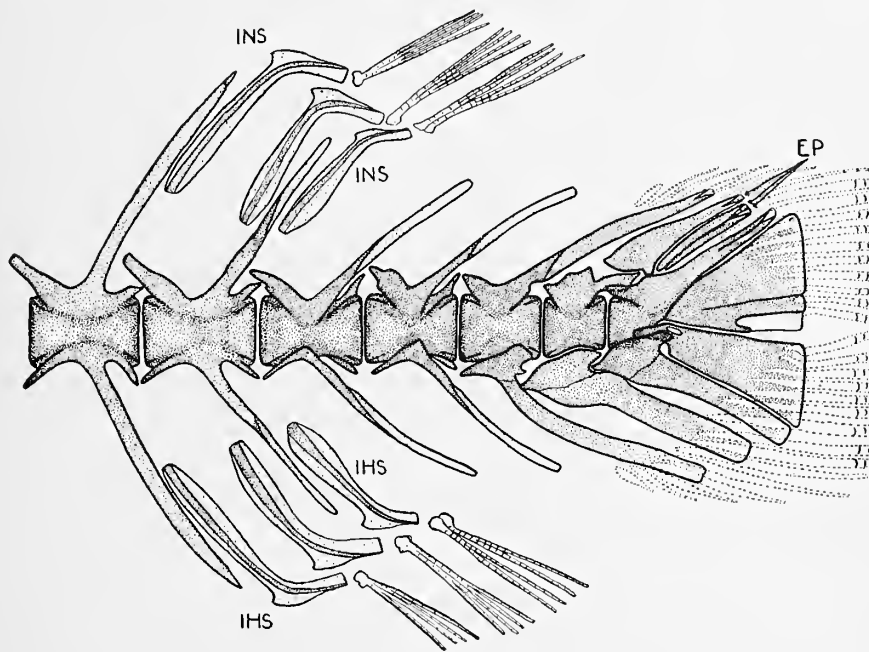
15 interneurals in the caudal region.

Bases of the haemal processes arising on the anterior half of the centra.

No short or stout posterior neural and haemal spines.

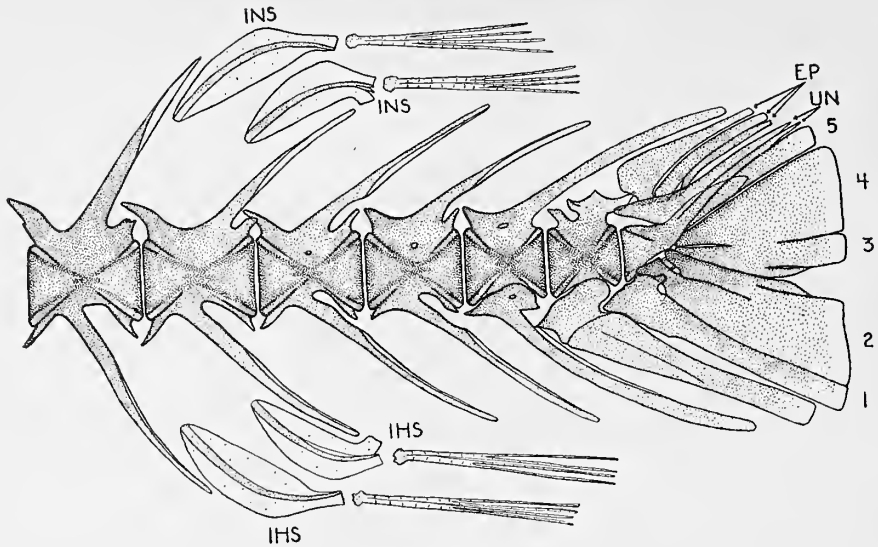
Material Studied.

The following description is taken from one



Text-figure 10.

Trachinotus palometa. Tail of 119 mm. specimen with three epurals. One interneural and one interhaemal spine is associated with the 4th vertebra from the urostyle. $\times 3.6$.



Text-figure 11.

Trachinotus goodei. Tail of 54 mm. specimen with three epurals and evidence of two pairs of uroneurals. Two interneurals and two interhaemals associated with the 5th vertebra from the urostyle. $\times 8.5$.

specimen caught in Bermuda, KOH Cat. No. 438, length 54 mm.

Caudal Osteology.

Urostyle: The anterior part of the urostyle is cone-shaped and its margin similar to the posterior part of the penultimate centrum. The reduced posterior tip of the urostyle is hidden and consolidated with the base of the uroneurals. The uroneurals protect the dorsal and posterior part of the urostyle and the bases of the hypurals about its ventral and posterior surface.

Uroneurals: These paired bones are unlike those of the other species studied in this paper. For a complete interpretation a series of younger specimens is needed. In this 54 mm. fish there are two pointed tips which form part of the hypural margin. Each represents paired lateral bones, the bases of which partly overlap the urostyle and the fifth hypural. The anterior dorsal uroneural extends from above the anterior margin of the urostyle where it is deep and wing-shaped and where bases of the epurals are inserted between its lateral bones. It extends posteriorly and dorsally and diminishes into a slender bone with a pointed distal tip. The second uroneural is similar distally but it arises immediately on the anterior part of the urostyle centrum. It overlaps the base and dorsal surface of the fifth hypural for all but the distal tip end. A broad, thin, paired bone covers part of the anterior half of the uroneurals and the fifth hypural. In our specimen of *Trachinotus palometa* of 119 mm. in length, only one pair of uroneurals can be found if the second pointed tip is to be interpreted as the fifth hypural. A series of young specimens is necessary in the case of both species to inter-

pret adequately the development of this part of the hypural complex.

Hypurals: There are two hypurals ventral and two dorsal to the median line. In the second large hypural there is definite evidence of a division of this bone, for there remains a suggestion of a double base with a line extending from here for half the length of the hypural. In none of the Bermuda carangids has this second hypural appeared as two separate bones, even in the very young of several species. This is the reason for consistently designating this particular hypural as a single bone. Its counterpart, the large hypural dorsal to the median line, has shown in several young specimens that it is formed by the fusion of two separate bones, which gives a criterion for calling this hypural three and four.

In this specimen hypurals three and four are distinct both anteriorly and posteriorly and only a small area in the center has fused beyond identity of the two separate bones. The fifth and most dorsal hypural is similar in size at its distal extremity to the first hypural and balances this bone in its position in the hypural fan. Its length, however, is less and the median end diminishes to a wedge-shaped tip.

Epurals: There are three epurals, which is also true of *Trachinotus palometa*. But in the species of this description the epurals appear more separate and individual than in *Trachinotus palometa*, which is a larger and older specimen. In this 54 mm. *Trachinotus goodei* the first or anterior epural is the largest, the second intermediate and the third, or posterior, the smallest. This is true of both their lengths and widths. The ventral ends are inserted between the lateral bones of the uroneurals. This is not so in the other species.

5. *Argyreiosus vomer* (Linnaeus).

(Text-figures 12, 13).

Diagnostic Characters:

The caudal skeleton is conspicuously deeper and relatively shorter than any of the other species treated.

3 anterior caudal haemal spines with triangular projections on the anterior surface at mid-length.

3 short posterior neural and haemal spines stout and club-like.

Material Studied.

This description is from a study of three specimens presented by the American Museum of Natural History. Cat. No. 14,184 from Pompano, Florida; KOH Cat. No. 2321, length 18 mm. Cat. No. 12,505 from Mastic, L. I.; KOH Cat. No. 2322, length 45 mm. Cat. No. 13,583 from Rio de Janeiro; KOH Cat. No. 2323, length 140 mm.

Caudal Osteology.

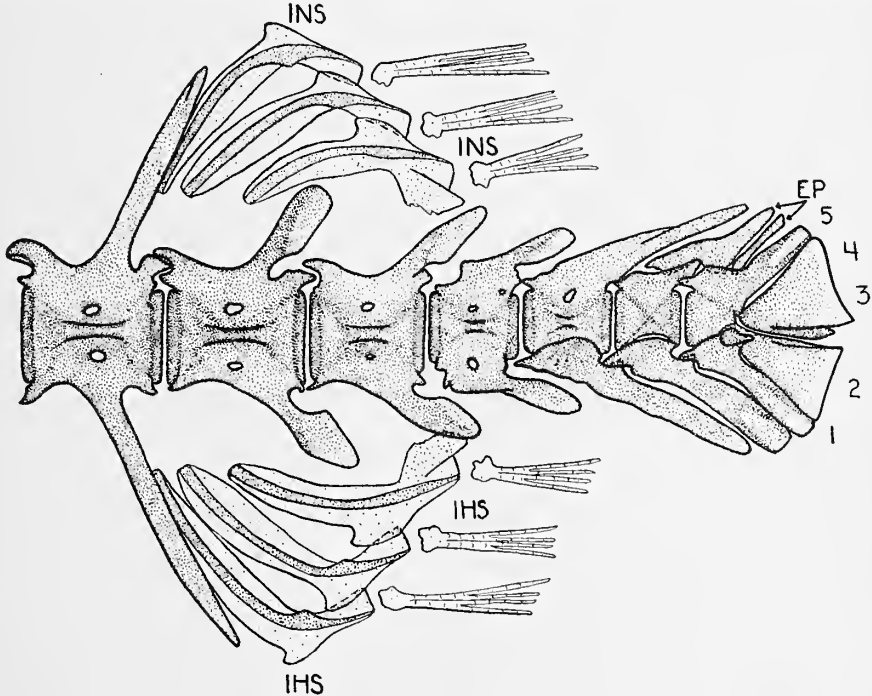
Urostyle: In the adult specimen of 140 mm. in length the posterior end of the urostyle is consolidated with the dorsal bones and cannot be distinguished.

In our young specimen of 18 mm. the urostyle extends dorsally to the hypural margin. Anteriorly, the urostyle is almost a perfect half

centrum but at the base of the second hypural it turns abruptly and extends in an oblique-dorsal direction and becomes a slender tapering rod. At the basal tip of the fifth hypural a mark appears which indicates consolidation in this youthful stage of the urostyle. The bases of all of the hypurals are separate from the urostyle with the exception of the fifth hypural whose anterior surface is in conjunction with the urostyle.

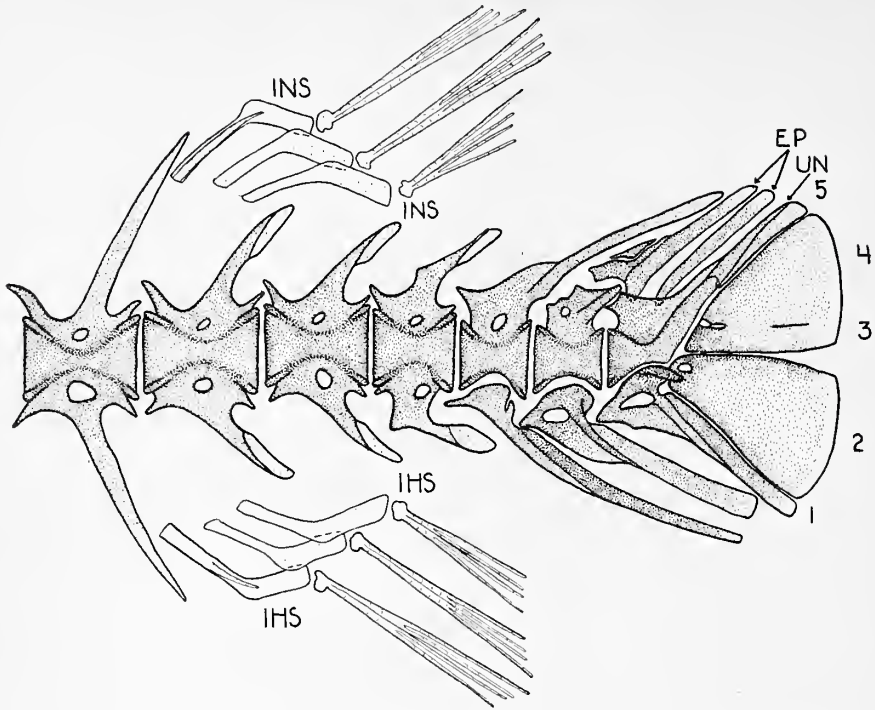
Uroneurals: There is a single pair of uroneurals which are more distinct in the 18 mm. specimen than in the two older stages. In the smallest fish the anterior part is already enlarged and fills the area dorsal to the urostyle but the spool-shaped urostyle is distinct. In the largest specimen the urostyle and the uroneurals have become one and there is only a suggestion of the urostyle as such. Both the anterior and the posterior portion of the uroneurals have increased in proportions. Distally, the uroneurals and fifth hypural have fused and there is only a suggestion of the hypural which in the 18 mm. specimen was a distinct bone.

Hypurals: In the adult specimen there are four hypural bones, two below and two above the median line. In the 18 mm. fish it is clear that the large hypural dorsal to the median line is the result of the fusion of two bones. Truly young specimens would undoubtedly show this as they have in several other species in this paper. The dorsal, or fifth hypural, is distinct in the 18 mm. specimen but in the 140 mm. fish it has be-



Text-figure 12.

Argyreiosus vomer. Tail of 140 mm. specimen. The bones of this deep-bodied fish are conspicuously stout and the centra less elongate than in the other species. $\times 3.23$.



Text-figure 13.

Argyreiosus vomer. Tail of 18 mm. specimen showing the posterior end of the urostyle, the uroneurals and the fifth hypural. These are not distinct in the 140 mm. fish. There is a hint of the division of the 3rd and 4th hypurals. $\times 25.2$.

come one with the uroneurals. The first hypural is not as massive as the corresponding bone in the adult, and there is a conspicuous large hole in the base or arch area. This is present in most of the neural and haemal bases but in the largest specimen the holes have disappeared in the three posterior processes and become smaller in the preceding arch bases.

Epurals: There are two epurals. In the 18 mm. specimen their shape in general is similar with the exception of the anterior projection on the first bone, which is a growth character. In no respect do these two bones resemble one another in the 140 mm. specimen. The anterior projection from the base of the first epural has become solid and massive and fills the area above the reduced neural process of the penultimate centrum. The rod-like form of the young specimen has disappeared entirely. The second or posterior epural has changed very little from that of the young stage. The ventral ends of both epurals in all three stages are inserted between the lateral bones of the uroneurals.

Additional Characters Worthy of Note: As is typical of this deep bodied species, the interneural and interhaemal spines are massive in the adult specimen. In each there is a central shaft which is heavily ossified and has lateral projections on the horizontal part. In the smallest specimen there is the beginning development of

this projection and all other parts of these bones are only slightly ossified. Several anterior caudal haemal spines are unique in development as compared with the other Bermuda Carangidae. The first and second are usually stout and at mid-length their surfaces abut. The three following haemal spines are also stout and have on their anterior sides heavy triangular projections. These are present in all three stages. This is illustrated in the Key (Text-fig. 5).

6. *Trachurops crumenophthalma* (Bloch).

(Text-figure 14).

Diagnostic Characters:

The posterior group of two interneurals and two interhaemals associated with the fourth vertebra from the urostyle.

The haemal processes of several precaudal centra are crescent-shaped and the spines arise on the anterior half of the centra.

Material Studied.

Three specimens were used for this description and all were caught in Bermuda. Cat. No. 9,140, KOH Cat. No. 615. Cat. No. 9,140, KOH Cat. No. 614, length 115 mm. Cat. No. 25,147, KOH Cat. No. 1135, length 108 mm.

Caudal Osteology.

Urostyle: In all specimens studied the posterior end of the urostyle is embedded in the terminal bones. The bases of the uroneurals and the hypurals surround this area. The anterior part of the urostyle is almost a perfect half centrum in shape and size. The dorsal surface is covered by the heavy uroneurals and the ventral surface by the base of the first hypural.

Uroneurals: There appears to be but a single pair of uroneurals. In our adult specimens these paired bones are massive and extend obliquely backward and dorsally from above the anterior part of the urostyle to the distal margin of the hypurals. In the anterior area a small portion of the ventral ends of the epurals are wedged between the lateral bones of the uroneurals. The oblique distal part probably represents the fifth hypural fused with the uroneurals. Our material is too advanced in development to illustrate this fact, which is found in the young specimens of the closely related genera.

Hypurals: Our material shows two hypurals ventral to and two dorsal to the median line. The central bones are large and fan-shaped, which is characteristic of this family. Young specimens would undoubtedly show that the large dorsal hypural was formed by the fusion of two bones and also that the fifth hypural was separate. In these adult specimens the fifth hypural is fused with the uroneurals and not distinguishable from them. On the basis of repeated evidence in the young of several closely related genera the hypurals are considered as five, which is seen in the Text-figure 14.

Epurals: The two epurals fill the area above the penultimate centrum and the urostyle. The long projection of the first epural extends anteriorly above the reduced neural process of the penultimate centrum. The base is inserted between the uroneurals. The second or posterior

epural is long and slender and slightly enlarged at the ventral end, which lies between the uroneurals.

7. *Chloroscombrus chrysurus* (Linnaeus).

(Text-figures 15-18).

Diagnostic Characters:

26 or 27 interhaemals in the caudal region.

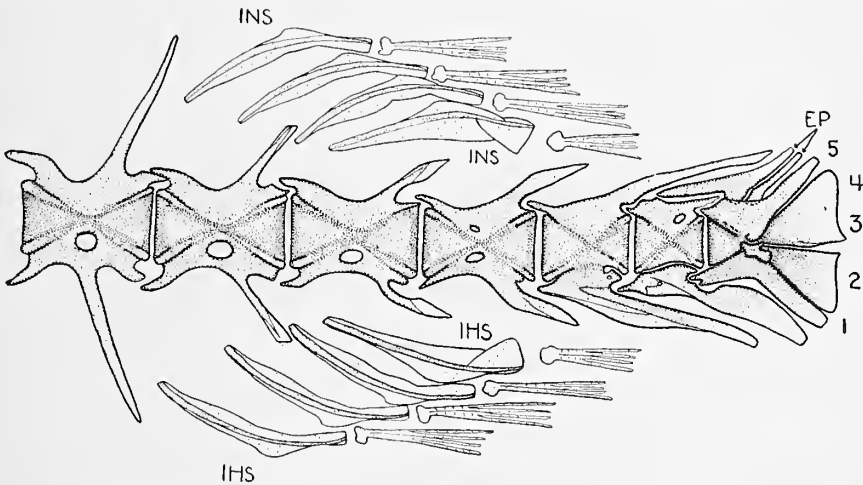
6 interhaemals between the first and second anterior caudal haemal spines.

Material Studied.

The following description is based on seven specimens taken in Haiti. Cat. No. 6,842, KOH Cat. No. 2317, lengths 100 mm. and 80 mm. Cat. No. 7,183, KOH Cat. No. 2318, lengths 15, 10, 7.5, 6.5, 6 mm.

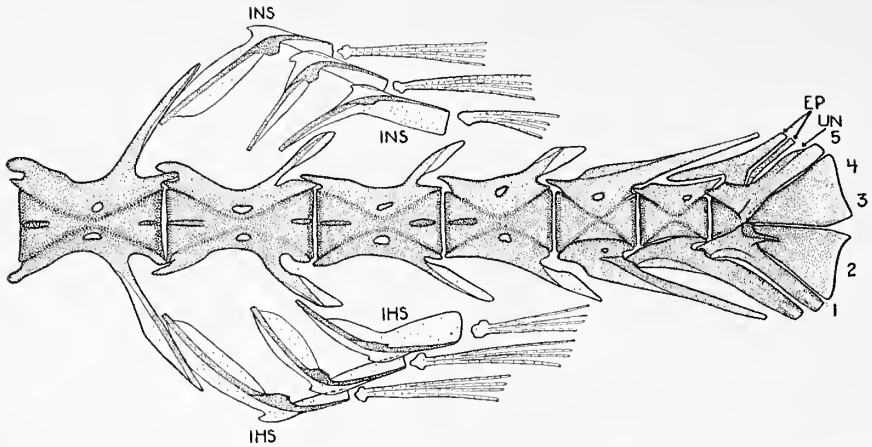
Caudal Osteology.

Urostyle: Four stages of development were found in specimens of 6 mm., 10 mm., 15 mm., and 100 mm. in length. In the largest fish, which is fully ossified, the posterior end of the urostyle is completely hidden by the overlapping uroneurals and hypurals. As in the other Bermuda Carangidae the anterior part of the urostyle is almost a complete half centrum and is similar in proportions to the adjacent part of the preceding centrum. In the 6 mm. specimen the urostyle is a long, slender, rod-like structure which extends from the posterior margin of the penultimate centrum to the distal margin of the hypurals. Anteriorly, the proportions are similar to the adjacent part of the preceding centrum. The urostyle extends posteriorly in an oblique and dorsal direction, tapering to about one-half the depth. The ossification is delicate throughout and ends midway between the bases of the fourth and fifth hypurals. A cartilaginous rod



Text-figure 14.

Trachurops crumenophthalma. Tail of 115 mm. specimen showing two interneurals and two interhaemals associated with the 4th and 5th vertebrae from the urostyle. $\times 11.65$.



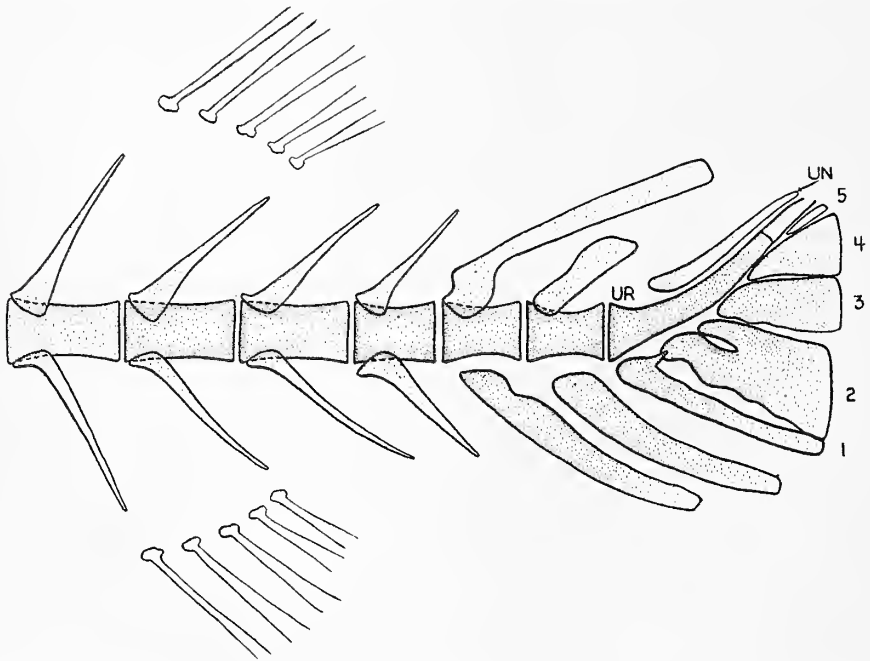
Text-figure 15.

Chloroscombrus chrysurus. Tail of 100 mm. specimen showing the 3rd and 4th hypurals fused and the 5th hypural united with the uroneurals. $\times 33.3$.

extends from here and disappears in the bases of the caudal rays. In the 10 mm. specimen ossification is more pronounced and the posterior dorsal end is seen at the center of the base of the fourth hypural. Anteriorly, the shape has begun to resemble that of the adult. The 15 mm. specimen shows still greater ossification and consolidation.

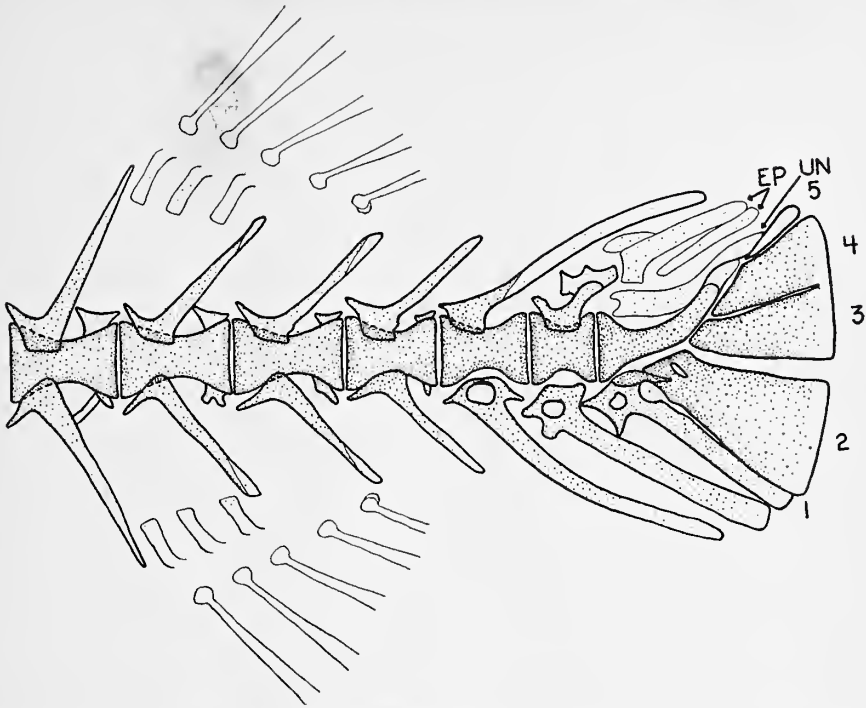
Uroneurals: There is a single pair of uroneurals, which in the adult is indicated only at the distal end. These bones have become fused with the

fifth hypural in the largest specimen. The three younger stages show clearly the development of the uroneurals. In the 6 mm. specimen this paired bone extends dorsally above the urostyle from the region of the second hypural to the margin of the hypurals. It is long and slender and the anterior end is slightly larger than the posterior tip. It is of importance to note the relation of this bone to the others and its independent position, which is found only in the very young stages.



Text-figure 16.

Chloroscombrus chrysurus. Tail of 6 mm. specimen which is partly ossified. There are no interneurals or interhaemals or epurals. The 3rd, 4th and 5th hypurals and the uroneurals are separate bones. The urostyle extends into the hypural margin. $\times 104$.



Text-figure 17.

***Chloroscombrus chrysurus*.** Tail of 10 mm. specimen showing increased ossification. The centra are spool-shaped and the epurals, uroneurals and base of the interneural and interhaemal spines have appeared. The 3rd and 4th hypurals have begun to fuse and the uroneurals about the fifth hypural. $\times 83$.

In the 10 mm. specimen the uroneurals have increased anteriorly both in depth and length and almost reach the anterior margin of the urostyle. The shape of this end has changed from a blunt rounded tip to a deeper indented form. The posterior part is reduced and the distal end appears in conjunction with almost half the proximal length of the fifth hypural. In this region the uroneurals have grown over the urostyle. The anterior part is still separate from the urostyle.

In the 15 mm. specimen the uroneurals resemble the structure of the adult more than the 10 mm. specimen, and the shape and proportions are similar. The base of the uroneurals has fused with the dorsal surface of the urostyle and in only one place is there any indication of the youthful stage where all the under part of this bone was entirely separate. There still remains two perforations or unossified areas. The anterior part of the uroneurals about the reduced neural process of the penultimate centrum and extend dorsally almost to the distal margin of the fifth hypural. In this stage the uroneurals have become entirely consolidated with the dorsal surface of this fifth hypural.

Hypurals: In the adult 100 mm. specimen there are two hypurals below and two above the median line. The first and fifth hypurals are the same size distally and flank the ventral and dorsal

part of the hypural fan. Two large hypurals form the central part of the hypural complex; one below and one above the median line. From a study of the young specimens it is certain that the large dorsal hypural is formed by the fusion of two bones and that the fifth hypural has fused with the uroneurals.

In the 6 mm. specimen, which is the youngest stage available for study of the Bermuda Carangidae, there are five distinct hypural bones. The first, or anterior bone, is long and slender and slightly enlarged at the median base. This base, which is the haemal arch, develops rapidly in the 10 mm. and 15 mm. stages. In the smaller fish a square, wing-like growth projects anteriorly and abuts the haemal process of the preceding centrum and there is a large hole or unossified area in the center of this growth. In this stage the lateral ridge, for the muscle attachment, is a small triangular projection from the base and overlaps slightly the base of the second hypural. In the 10 mm. specimen this ridge has more than doubled in size and proportion.

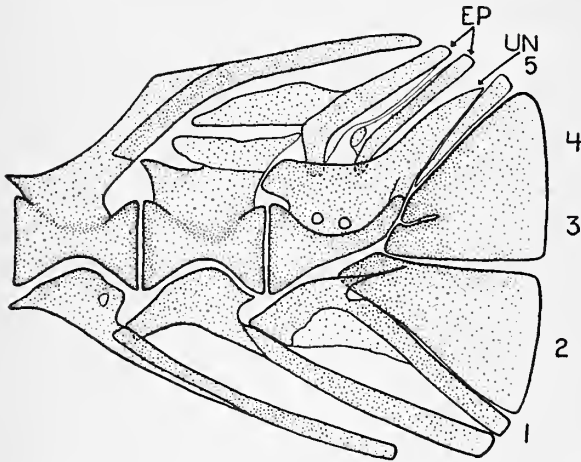
The first hypural of the 15 mm. specimen resembles the corresponding bone of the adult fish with the exception of the density of ossification, and extent of development of the muscle attachment process, and proximity to the ventral surface of the urostyle. There is still considerable space between the haemal arch and the urostyle,

which entirely disappears in the adult specimen. This is also true of the preceding haemal arches.

The second hypural changes less in shape and proportions than any of the other hypural bones. In the 6 mm. specimen the base is divided into two by a long oval slit which extends for about one-quarter the length of the bone. In the 10 mm. specimen the two bases have fused but a small oval hole remains. In the 15 mm. fish there is no indication of either the two bases or the slit of the younger stages. The third and

form part of the caudal margin. In the 15 mm. specimen the degree of ossification is identical with the other caudal bones. The shape of both epurals is similar to that of the adult, and the median ends are inverted between the uroneurals, which is also an adult character.

Additional Characters Worthy of Note: The illustrations show the increase in ossification with age and also the change in shape and proportions of all of the caudal bones. In the 6 mm. specimen there is no evidence of epurals, inter-



Text-figure 18.

***Chloroscombrus chrysurus*.** Tail of 15 mm. specimen. The posterior end of the urostyle is reduced and the distal portion of the uroneurals flank the side of the 5th hypural. In the 100 mm. specimen these two bones have fused. $\times 42$.

fourth hypurals are separate bones in the youngest stage and in the 10 mm. specimen their distal margin has fused and the space between become less. The 15 mm. fish still has two bases which represent the two separate bones of the younger stage but the slit between has diminished by more than half its former length. In the 100 mm. specimen there is no trace of a slit or double base. The fifth hypural appears as a very small wedge-shaped bone between the distal end of the urostyle and the fourth hypural. Its growth and development from this stage to the adult is remarkable and without several very young specimens this hypural would not be identified as an hypural bone. In the youngest stage this bone is entirely separate from the surrounding structures. In the 10 mm. fish the bone has increased in length and depth and about one-half of its anterior length abuts the uroneurals on the dorsal surface. In the 15 mm. specimen the length is greatly increased and all but a small part of the dorsal end is in conjunction with the uroneurals. The adult specimen of 100 mm. shows that the fifth hypural and the uroneurals have fused and all that remains of their separate identity is a light line at the distal extremity.

Epurals: There are two epurals in this species. Neither of these bones can be found in the 6 mm. fish. In the 10 mm. specimen these epurals appear with delicate ossification and as long slender bones. The anterior epural is longer and broader than the second one and has the beginning of the anterior projection near the median end. Both bones are free and their distal tips

neurals and interhaemals. The centra are rectangular in shape with considerable distance between their margins. In the 10 mm. specimen the spool-shape of the centra begins to change and to resemble the adult. The epurals are lightly ossified and also the interneurals and interhaemals. The zygapophyses are present on the dorsal and ventral surfaces of the centra. With the consolidation from a long rectangular structure to a shorter spool-shaped centra the neural and haemal processes appear to shift from their youthful anterior position to a central position. The three reduced posterior neural and haemal spines of the adult are simple and unmodified in the 6 mm. and 10 mm. specimens.

8. *Caranx ruber* (Bloch).

(Text-figure 19).

9. *Caranx bartholomaei* Cuvier & Valenciennes

Diagnostic Characters (both species):

Total of 24 interhaemals in the caudal region.

Total of 22 interneurals in the caudal region.

4 interhaemals between the first and second anterior caudal haemal spines.

3 interneurals and 3 interhaemals in posterior group in three specimens. The oblique part more slender than in the two following species.

Minor species differences cited in Key and in text.

Material Studied.

Caranx ruber; one specimen taken in Haiti. Cat. No. 7,016, KOH Cat. No. 2320, length 160 mm.

Caranx bartholomaei; two specimens caught in Bermuda. Cat. No. 25,057, KOH Cat. No. 1074, length 50 mm. Cat. No. 25,065, KOH Cat. No. 1073, length 52 mm.

Caudal Osteology.

Urostyle: The reduced terminal end is hidden in both species by the heavy uroneurals on the dorsal and the base of the hypurals on the ventral surface. No small specimens are available to show the development. The anterior part is cone-shaped and of the same proportions as the posterior half of the penultimate centrum. The dorsal surface is covered by the uroneurals and the ventral by the first hypural in *Caranx ruber* (Text-fig. 19). In *Caranx bartholomaei*, which is one-third the length, the base of the first hypural is still separate from the ventral surface of the urostyle.

Uroneurals: In the 50 mm. specimen of *Caranx bartholomaei* there is indication of one pair of uroneurals. At the distal end the line of junction between the uroneurals and the fifth hypural still remains. There is no evidence of this in the 160 mm. specimen of *Caranx ruber*. In this species the two bones have fused.

Hypurals: In both species there are two hypurals which are ventral to and dorsal to the median line. Their positions and proportions are similar in the corresponding bones. Because of facts presented by several young stages in closely related genera in this family, the hypural bones of these species are numbered 1 to 5 in the illustration.

Epurals: There are two epurals in both species and the corresponding bones are similar in shape

and position. In the distal dorsal portion of the smaller *Caranx bartholomaei* the epurals are more slender. This has been found to be an age character in other genera.

Additional Characters Worthy of Note: In *Caranx ruber* the posterior neural zygapophyses have hook-like projections on the dorsal surface. This is shown in the anterior vertebra in the illustration. The development is especially prominent in the central caudal area. In *Caranx bartholomaei* the dorsal surfaces of the corresponding zygapophyses are smooth. There is also a difference in the development of the anterior neural zygapophyses of the two species. In *Caranx ruber* the surfaces are jagged and notched, especially in the central caudal area, but this is not true in *Caranx bartholomaei*. In a detailed study of the two species many minor differences such as these distinguish each as a different species.

10. *Caranx crysos* (Mitchill).11. *Caranx latus* Agassiz.

(Text-figure 20).

Diagnostic Characters (both species):

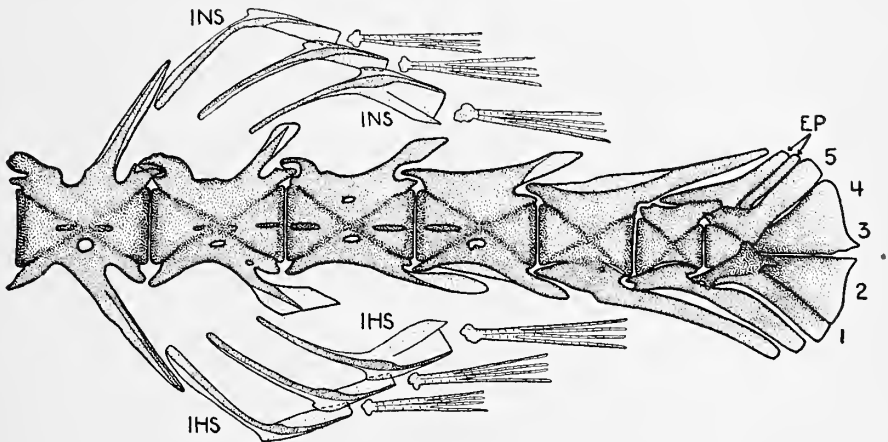
Total of 17 to 20 interhaemals in the caudal region.

Total of 15 to 18 interneurals in the caudal region.

3 interhaemals between the first and second anterior caudal haemal spines.

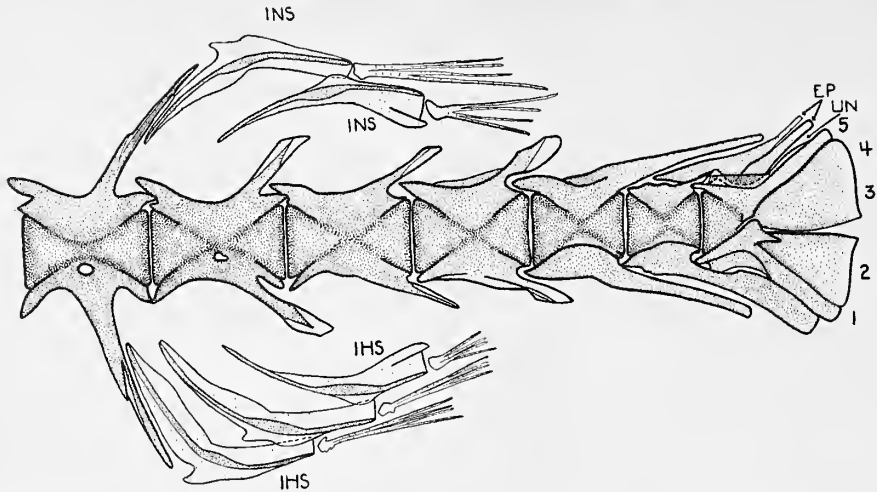
2 interneurals and 2 or 3 interhaemals in the posterior group in the five specimens studied. The oblique part broader than in the two preceding species.

Minor species differences are cited in the Key and in the text.



Text-figure 19.

Caranx ruber. Tail of 160 mm. specimen. This figure represents both this species and *Caranx bartholomaei* which in gross structure are similar. $\times 2.74$.



Text-figure 20.

Caranx latus. Tail of 87 mm. specimen. This figure represents both this species and *Caranx crysos*, the gross structure being similar. $\times 15.87$.

Material Studied.

Caranx crysos; one specimen taken in Haiti. KOH Cat. No. 2319, length 130 mm.

Caranx latus; four specimens caught in Bermuda. KOH Cat. No. 1070, length 44 mm. KOH Cat. No. 412, length 63 mm. KOH Cat. No. 649, length 80 mm. KOH Cat. No. 1040, length 87 mm.

Caudal Osteology.

Urostyle: The anterior part of the urostyle in both species is cone-shaped and almost identical in shape with the posterior half of the preceding centrum. The dorsal surface is fused with the bases of the uroneurals and the ventral surface with the base of the first hypural. The posterior end cannot be distinguished in specimens as old as those in this collection. Text-figure 20 represents both species.

Uroneurals: In the 87 mm. specimen of *Caranx latus* one pair of uroneurals is found where it has fused during growth with the fifth hypural. In *Caranx crysos*, which is 130 mm. in length, there is no evidence left and the fifth hypural and uroneurals appear as one structure.

Hypurals: In both species there are two hypurals below and two above the median line. They are similar in proportions and arrangement to the other species of *Caranx*. None of these specimens are young enough to show the development and eventual fusion of the hypurals but the figure is numbered to show the position of five hypurals which the young of closely related genera have demonstrated.

Epurals: There are two epurals, as in all but one genus of Carangidae. In the distal portion of the smaller *Caranx latus* these bones are more slender than those of *Caranx crysos*. This development is correlated with age in other genera.

Additional Characters Worthy of Note: In *Caranx crysos* there are 20 interhaemals in the caudal region and 18 interneurals. There are fewer in *Caranx latus*, which has 17 interhaemals and 15 or 16 interneurals in the caudal region. The shapes and proportions of the zygapophyses differ in the two species, also the presence and absence of neural and haemal arch perforations. In a detailed study of the minor differences in both species these can be distinguished as two separate species.

SUMMARY.

The following facts correlate the salient similarities found in the study of Bermuda Carangidae.

Vertebral count: 10 trunk plus 14 caudal in all species but *Caranx crysos* and *Decapterus punctatus*. These have 10 trunk and 15 caudal. In both, only one specimen was available for the count.

Caudal fin count: There is only slight variation among the species. The illustration of *Trachinotus palometa* (Text-fig. 10) shows the arrangement. It is usually 6 raylets plus 11 rays dorsal; 6 raylets plus 9 rays ventral, making a total of 17 dorsal, plus 15 ventral.

Epurals: There are two epurals in all but the genus *Trachinotus*, which has three.

Hypurals: In the adults of all species there are four hypurals; two below and two above the median line. The two central bones are large and fan-shaped. The dorsal or fifth hypural is fused with the uroneurals in all adults. In the young stages it is separate. In young stages the large dorsal hypural is found to be formed by the fusion of two separate bones. There remains a hint in several of the young of a one-time division of the large ventral or second hypural. This is not complete in any specimens of this

family. In all Bermuda Isospondyli and Iniomi there are at least three hypurals below the median line.

Uroneurals: In all species but *Trachinotus goodei* there is a single pair of uroneurals. Here there is a suggestion of a second pair, but young specimens are necessary to ascertain this fact.

Elongate spines in caudal complex: In the adult of all species one long neural spine and two long stout haemal spines form the anterior part of the caudal complex.

Anterior caudal haemals: *Decapterus* is the only genus in this series which has the bases of

the first few anterior caudal haemals crescent-shaped and situated on the anterior half of the centra. The typical shape is triangular.

Pre-caudal haemals: *Decapterus* and *Trachurops* have crescent-shaped precaudal haemal bases which are situated on the anterior half of the centra.

Specialized neural process: Adult specimens of all species of Bermuda Carangidae have a reduced neural process on the penultimate centrum. The long anterior projection from the first epural extends into the area above this process.

ISHES.

Caranx ruber

Posterior neural zygapophyses with hook-like projections on the dorsal surfaces, especially in the central caudal area.

Anterior neural zygapophyses with notched dorsal surfaces especially in the central caudal region.

Group A

interhaemals and 20 to 22 interneurals in caudal region.

interhaemals between the first and second anterior caudal haemal spines.

GROUP I
3 posterior neural and
mal caudal spines
spicuously short or st
2 epurals.



Text-figure 1.

Caranx bartholomaei

No hook-like projections on dorsal surfaces of posterior neural zygapophyses.

Anterior neural zygapophyses with smooth dorsal surfaces.

Caranx crysos

20 interhaemals and 18 interneurals in caudal region.

Group B

to 20 interhaemals and 15 to 18 interneurals in caudal region.

interhaemals between the first and second anterior caudal spines.

GROUP II
No conspicuously short
terior neural and h
spines.
3 epurals.

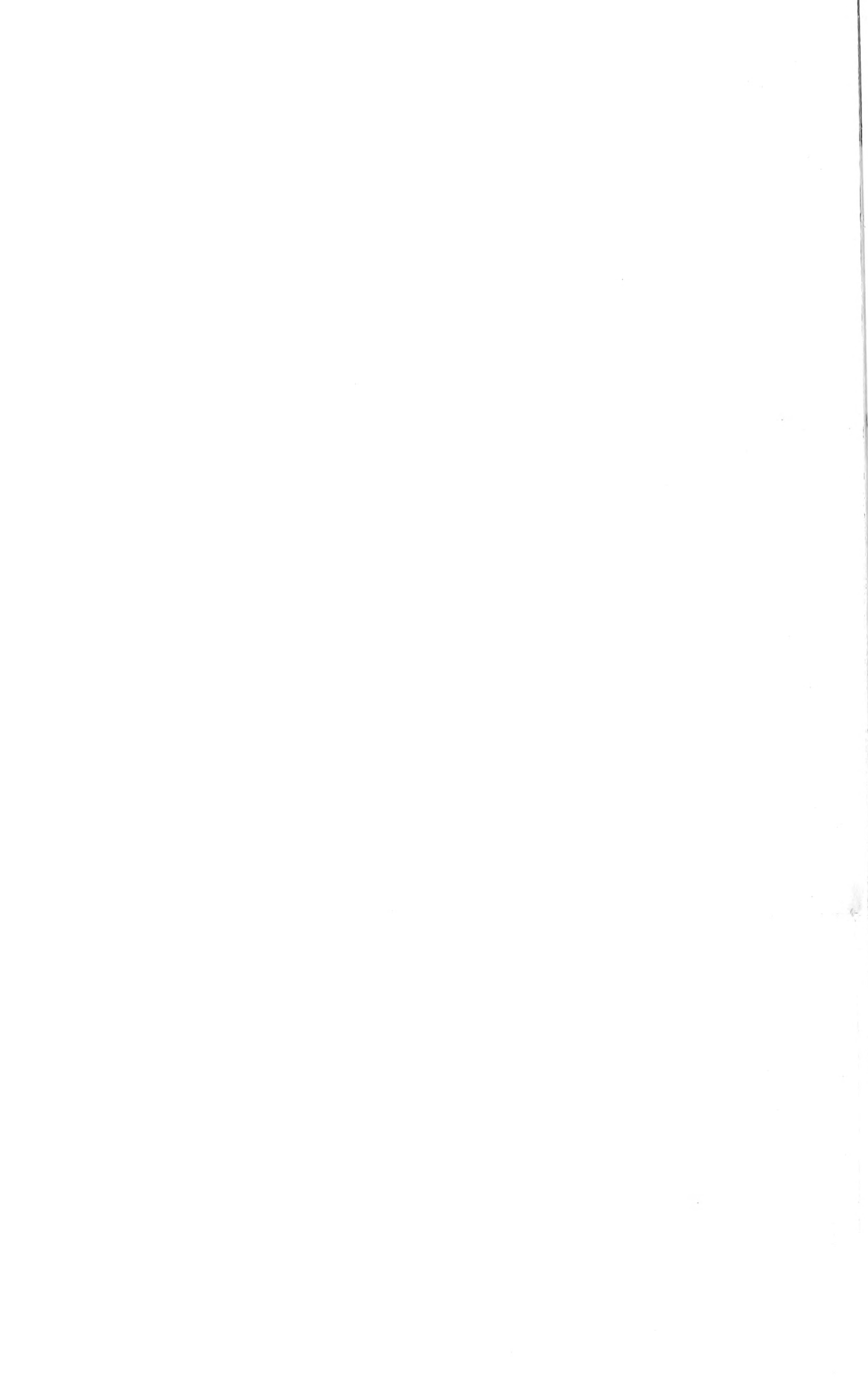


Text-figure 2.

Caranx latus

17 interhaemals and 15 or 16 interneurals in caudal region.

C
A
R
A
N
G
I
D
A
E



KEY TO CAUDAL SKELETON OF BERMUDA SHALLOW WATER CARANGID FISHES.

(Text-figs. 1-6).

Decapterus macarellus

1 interneural and 1 interhaemal arising over the 4th vertebra anterior to the urostyle. The horizontal part about one and a half times longer than the anterior oblique part.

Sub-Group A

Horizontal length of posterior inter-neural and inter-haemal conspicuously longer than the preceding spines.

1st anterior caudal haemal arch crescent-shaped and on anterior half of centrum.



Text-figure 3.

Decapterus punctatus

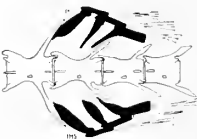
2 interhaemals and 2 interhaemals arising over the 4th vertebra anterior to the urostyle.

The horizontal part only a little longer than the oblique part.

Sub-Group B

Horizontal length of posterior inter-neural and inter-haemal not conspicuously long and the general shape the same as the spines immediately preceding.

1st anterior caudal haemal arch not crescent-shaped and on entire centrum.



Text-figure 4.

Trachinotus palometa

1 interneural and interhaemal spine over the 4th vertebra from the urostyle. 17 interneurals in caudal region.

Trachinotus goodiei

2 interneural and interhaemal spines over the 5th vertebra from the urostyle. 15 interneurals in caudal region.



Text-figure 2.

Division I

Argyreiosus vomer

3 anterior caudal haemal spines with triangular projections at mid-length.

Posterior vertebrae relatively shorter and more massive than in Division II.



Text-figure 5.

Sub-Division A

Trachurops crumenophthalma

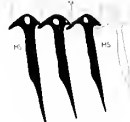
Posterior group of interneurals and interhaemals associated with 4th vertebra from the urostyle.

Precaudal haemal process crescent-shaped and on anterior half of centrum.

Division II

No triangular projections on anterior caudal haemals.

Posterior vertebrae relatively longer and more slender than in Division I.



Text-figure 6.

Group I

Chloroscombrus chrysurus

26 or 27 interhaemals.

6 interhaemals between the first and second anterior caudal haemal spines.

Sub-Division B

Posterior group of interneurals and interhaemals associated with 5th vertebra from the urostyle.

Precaudal haemal process triangular-shaped and covers all of centrum.

Group II *Caranx*

Less than 26 interhaemals.

3 or 4 interhaemals between the first and second anterior caudal haemal spines.

Caranx ruber

Posterior neural zygapophyses with hook-like projections on the dorsal surfaces, especially in the central caudal area.

Anterior neural zygapophyses with notched dorsal surfaces especially in the central caudal region.

Sub-Group A

24 interhaemals and 20 to 22 interneurals in caudal region.

4 interhaemals between the first and second anterior caudal haemal spines.

Caranx bartholomaei

No hook-like projections on dorsal surfaces of posterior neural zygapophyses.

Anterior neural zygapophyses with smooth dorsal surfaces.

Caranx crysos

20 interhaemals and 18 interneurals in caudal region.

Sub-Group B

17 to 20 interhaemals and 15 to 18 interneurals in caudal region.

3 interhaemals between the first and second anterior caudal spines.

Caranx latus

17 interhaemals and 15 or 16 interneurals in caudal region.



9.

Description of an Egg of the Long-tailed Bird of Paradise.

LEE S. CRANDALL.

Plate I.

On June 16, 1937, a pair of Long-tailed Birds of Paradise, *Epimachus meyeri meyeri* Finsch, collected by F. Shaw Mayer "near the head of the Waria," were received at the Zoological Park. During following years, frequent displays of the male were noted but as this is a common practice in the group and there was no evidence of nesting activity, we expected no further result. However, the female was noticed in comatose condition on the afternoon of February 28, 1941, and on examination was found to be egg-bound. She responded well to treatment and the egg was safely laid about two hours later.

Since the egg of this species appears to be undescribed, the following notes are given.

The egg measures 44.25×28.5 mm. Its weight was 18.9 grams or approximately .62 ounces. The ground color is buff (close to Cartridge Buff of Ridgway). It is heavily blotched and streaked at the large end, the markings decreasing toward the small end, which is almost clear. The under markings are grayish (close to Pale Mouse Gray of Ridgway) while those on the surface are reddish-brown (near Russet of Ridgway).

EXPLANATION OF THE PLATE.

PLATE I.

Fig. 1. Egg of *Epimachus meyeri meyeri* Finsch.
Actual size.



FIG. 1.

DESCRIPTION OF AN EGG OF THE LONG-TAILED BIRD OF PARADISE.



10.

On the Uterine Young of *Dasyatis sabinus* (Le Sueur) and *Dasyatis hastatus* (De Kay).

C. M. BREDER, JR. & LOUIS A. KRUMHOLZ

New York Aquarium and University of Illinois.

(Text-figures 1 & 2).

The small sting ray, *Dasyatis (Amphotistius) sabinus* (Le Sueur) is abundant along the west coast of Florida in the vicinity of the field station of the New York Aquarium on Palmetto Key. Here mature gravid females may be found at sizes not greatly exceeding those of the relatively newborn young of the much larger *Dasyatis hastatus* (De Kay).

Apparently there is a dearth of material in the literature concerning the size of gravid females, the number of young per individual and the sex ratios of the young. The catches of the stop-netters operating in Bull's Bay (Cara Pelau on the northern side of Charlotte Harbor on the U. S. coastal charts) provided the data of the accompanying tables, except as noted. The 1939 material was collected by M. B. Bishop of Peabody Museum, Yale University.

The sizes of some of the gravid females of *D. sabinus* did not greatly exceed those of the new-born young of *D. hastatus* taken on June 29. These latter ranged from 160 to 176 mm. in length, while one not quite mature male of the former was only 174 mm. long. Three full-term embryos taken from one female *D. sabinus* varied in length from 99 to 100 mm.

It can be seen that there is a steady increase in size of the embryos of *D. sabinus* from a mean of 35.8 mm. on June 19 to a mean of 99.6 on July 11. Also, there was no overlapping of the means and extremes on the various dates. If this can be taken to indicate the growth rate, on so few data, it is remarkably rapid.

If the length of the disc (from the tip of the snout to the posterior border of the disc) is compared with the width, it is seen that the two dimensions are nearly equal. Moreover, this relationship holds from the smallest embryos obtained through to the adult (Text-fig. 1), clearly showing it to be a straight line relationship. *D. hastatus*, which is a little wider than long, has a similar straight line relationship, but is not so close to a 45° angle. This is clearly a

most unusually constant growth rate for which there is no superficial explanation at this time. It is not of importance in intra-uterine life nor can it be in post-uterine life when the extremely different relationships of various other species of rays, otherwise much alike, are taken into consideration. The growth relationship of these is so constant that it might be simulated to flap-jack batter spreading out on a pan. Except in the early embryos, this relationship is sufficient to separate these two species which so closely resemble each other. Text-fig. 1 also indicates the relative sizes of the adults and also the size of the young at delivery.

A full-term young of each species is illustrated in Text-fig. 2 for purposes of comparison. The general shape and the presence of the keel on the tail of *D. hastatus* make separation simple. The folding in of the tail, at its origin from the body, in *D. hastatus* as compared with the flaring out in *D. sabinus* is another characteristic.

It was not always possible to identify each young fish with its mother, because in capture some of the females aborted, resulting in a mixture of mothers and young. These young, even though the yolk sac was still hanging outside the body, were able to swim around actively when placed in an aquarium. To avoid possible mistakes and confusion, the young have been considered in groups as taken. The material did show a variation in numbers of young from one to three in *D. sabinus* and from two to five for *D. hastatus*. On June 19, 1940, there was one gravid *D. sabinus* which carried but one embryo. This embryo was nearly twice the size of the others taken on the same date. However, on June 28, 1940, we took another female which carried but one embryo and this was very nearly the same size as others taken on the following day.

The sex ratios of all the embryos of *D. sabinus* combined (25) showed 56% to be male. However, one mother carried three female embryos.

TABLE I.
Size and Sex of *Dasyatis* Embryos.

		<i>Dasyatis sabinus.</i>									
Date	Disc in mm.		Sex	Female			Male		All		
	Length	Width		Max.	Mean	Min.	Max.	Mean	Min.	Mean	
4/9/39	55	55	m)								
Captiva Pass	49	48	f)	49	49	49	55	55	55	52	
6/19/40	30	29	f								
	33	32	f								
	33	30	f								
	50	53	f								
	33	30	m	50	38.5	30	33	33	33	35.8	
6/28/40	78	81	m	—	—	—	78	78	78	78	
6/29/40	71	72	f								
	74	77	f								
	82	81	f								
	83	87	f								
	68	69	m								
	69	67	m								
	70	71	m								
	70	73	m								
	70	74	m								
	71	72	m								
	71	74	m								
	74	75	m								
	75	76	m								
	77	79	m								
	79	81	m								
	79	81	m	83	77.7	71	79	72.9	68	75.2	
7/11/40	99	99	f								
East side of Useppa Island	99	99	f								
	100	101	f	100	99.6	99	—	—	—	99.6	
<i>Dasyatis hastatus.</i>											
4/9/39	76	83	f								
Captiva Pass	75	83	f	76	75.5	75				75.5	
4/10/39	97	102	m								
Captiva Pass	95	101	f	97	97	97	95	95	95	96	
6/24/40	85	87	f								
	82	88	f								
	86	87	m								
	85	89	m	82	82	82	85	85	85	83.5	
6/29/40	172	193	f								
	176	197	f								
	160	189	m								
	170	192	m								
	168	195	m	176	174	172	170	166	160	169.2	

The relatively few young of *D. hastatus* (9) showed 55.5% to be male. Since there were in all 12 gravid *D. sabinus* and 25 embryos, they averaged 2.08 per mother. The four *D. hastatus*

females averaged 3.25 per mother. These latter are much larger in relation to the size of the young they liberate; the difference in number seems to be purely mechanical.

TABLE II.
Size and Sex of *Dasyatis* Adults.
Dasyatis sabinus.

Date	Length	Width	Sex	
6/19/40	201	—	f	not gravid
	202	—	f	not gravid
	214	—	f	not gravid
	222	—	f	gravid
	223	—	f	gravid
Length to notch	244	—	f	gravid
	247	—	f	not gravid
	262	—	f	not gravid
	190	—	m	
	190	—	m	
	199	—	m	
	213	—	m	
	218	—	m	
	234	—	m	
	238	245	f	gravid
6/28/40	174	179	m	imm.
6/30/40	—	235	f	gravid
	—	241	f	gravid
	243	245	f	gravid
	—	254	f	gravid
	—	260	f	gravid
	—	286	f	gravid
	—	286	f	gravid
	220	224	m	
—	235	m		
7/11/40	291	297	f	gravid
<i>Dasyatis hastatus</i> .				
6/24/40	851	984	f	gravid
6/29/40	—	Circa 914	f	gravid
Unlabeled	272	310	f	not gravid

} 5 embryos

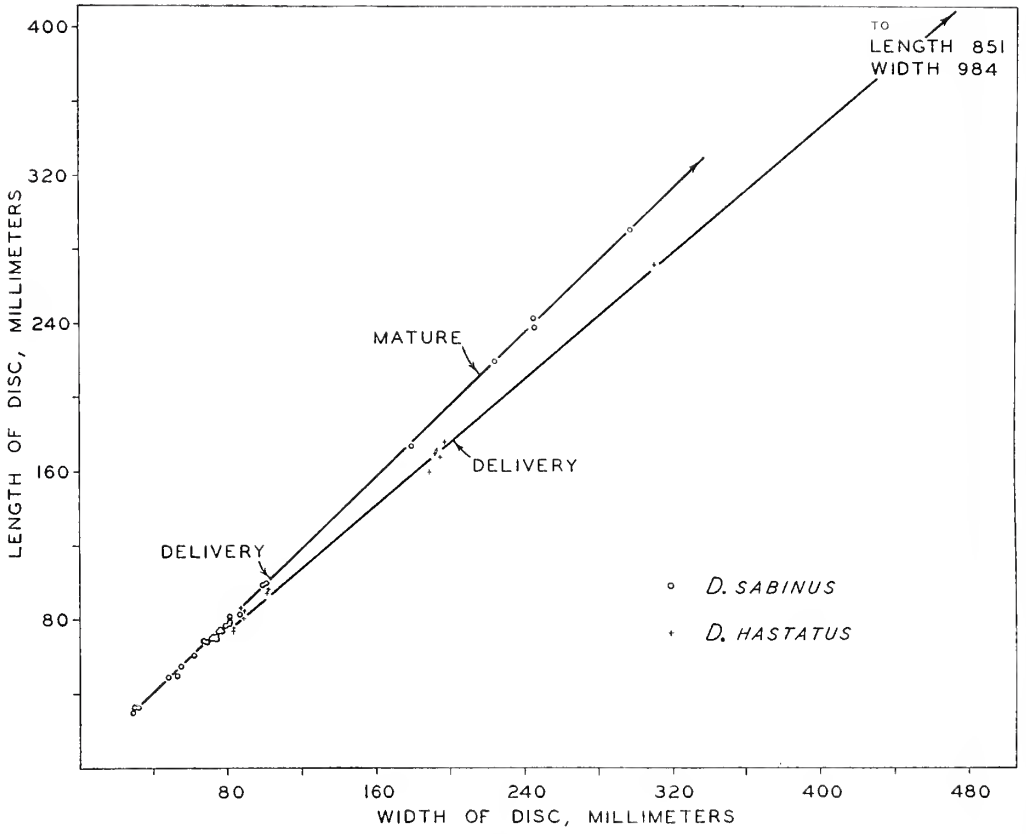
1 embryo

} 16 embryos

3 full term embryos (all females)

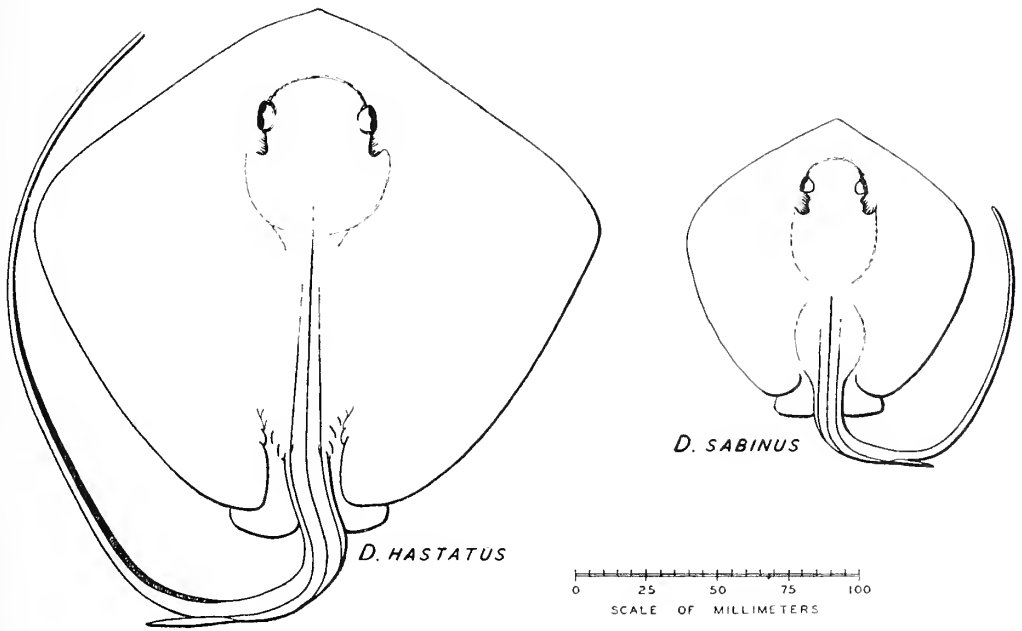
4 embryos

5 embryos



Text-figure 1.

Comparison of length and width of disc in pre-natal and post-natal *Dasyatis* based on data in Tables I and II.



Text-figure 2.

Dorsal view of full-term embryos of two species of *Dasyatis*.

11.

Additional Social and Physiological Aspects of Respiratory Behavior in Small Tarpon.

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INTRODUCTION.

Tarpon, *Tarpon atlanticus* (Cuv. & Val.), whose swimbladders contain considerable alveolar tissue, periodically rise to the surface to breathe atmospheric oxygen despite their extensive gill surfaces and the relatively high oxygen content of the waters they normally inhabit.

The work reported here represents a continuation of the program of investigation with small tarpon begun by Shlaifer & Breder (1940). In this earlier work, which, incidentally, is the first experimental report on this fish, it was found, among other things, that the surface rise of a tarpon to gulp air may induce similar rises in others in a group. For instance, in a group of four in a 50-liter aquarium, in 70% of the cases a rise by one tarpon would induce a rise in one or more companions. It was shown that "coincidence" was not involved as a disturbing factor and that, apparently, a tarpon had to be in a "physiologically receptive" state by virtue of a depleted oxygen supply before such imitative rises could be induced. In preliminary experiments, some success was attained in inducing rises by means of a silver-painted carved wooden tarpon model manipulated so as to simulate the normal rise of this fish. In the present report "model" experiments were considerably extended.

Shlaifer & Breder (1940) found that while the locomotor activity of tarpon did not change when the oxygen content of the water was raised from 2.50 cc. per liter to 5.60 cc., the rate of surface (respiratory) rises to gulp air decreased markedly. As a continuation of this line of investigation, experiments were performed to determine the effect of waters of distinctly low oxygen content on locomotor activity and surface rises; also, survival time was determined for tarpon whose access to the surface and hence to atmospheric oxygen was cut off.

The writer wishes to express his appreciation to Dr. C. M. Breder, Jr., of the New York Aquarium for the experimental animals and to the U. S. Fish and Wildlife Service at whose

Woods Hole laboratories the experiments were performed.

THE INDUCTION OF IMITATIVE
RESPIRATORY RISES.

As discussed above, it has been found (Shlaifer & Breder, 1940) that imitative surface rises in small tarpon may be induced by a manipulated wooden model as well as by other tarpon. Models have been used with and without success in various lines of investigation on behavior in fishes. Thus, Lissmann (1932) found that the characteristic fighting reaction of the Siamese fighting fish, *Betta splendens*, is elicited by plasticine models or paintings of the fish. Noble (1934) working with the dwarf sunfish, *Eupomotis gibbosus*, and Breder (1936) with the sunfish, *Lepomis auritus*, found that males would attempt to mate with a variety of objects irrespective of their general appearance provided they were manipulated so as to resemble somewhat the actions of a female ready to spawn. On the other hand, Spooner (1931) found that the bass, *Morone labrax*, was not attracted by various rough models of itself. Breder & Coates (1935), investigating the sex recognition of the guppy, *Lebistes reticulatus*, found that no reaction was given to carefully made models of female *Lebistes* with or without movement. Finally, Shlaifer (1940) failed to obtain a reaction to sunfish models by goldfishes.

Granted that a properly manipulated wooden model may induce imitative rises in tarpon, will other objects properly manipulated but differing appreciably from a tarpon in shape and color also induce rises and if so to what extent? Will a tarpon model or other objects be effective if manipulated so as to rise in a manner appreciably different from the normal one? In an attempt to answer these questions the experiments described below were performed.

Materials and methods. The animals used in these and other experiments described in this paper were 10-12 cm., presumably young, specimens sent from the collection at the New York

Aquarium but originally obtained along the Florida coast. They were kept in sea water and were fed chopped herring three times a week. The experimental group in the model tests was composed of six tarpon placed in 40 liters of standing sea water in a 48-liter rectangular assembled aquarium with transparent glass sides, whose dimensions were 55 cm. by 35 cm. and 25 cm. deep. The water temperature range was 19–22 degrees C. and the average oxygen content was 2.50 cc. per liter.

Four different types of object, all 10 cm. in length, were used as "models" in the attempts to induce imitative rises in the experimental animals. These were: 1. A silver-painted carved wooden model of a tarpon having no fins or mouth but possessing an "eye" fashioned out of a thumbtack. 2. A white spatula. 3. A piece of red rubber tubing 1 cm. in diameter. 4. A solid glass rod 4 mm. in diameter. Two pieces of string were attached to these objects at opposite ends. The object to be tested was suspended horizontally in the experimental aquarium containing the six tarpon, next to the long side of the aquarium nearest the observer, at a distance of 3.5 cm. from the bottom, the level at which the tarpon in that situation generally swam. The observer, seated about two feet away from the aquarium and facing one long side, manipulated the object by means of the two strings. The normal air-gulping rise of a tarpon is a rapid movement lasting a little less than a second from the start of the rise to the return to the normal position. Usually the animal rises to the surface almost vertically. In A of Table I this type of rise was simulated by properly manipulating the objects. In B of Table I the object or model was manipulated so as to produce a distinctly "abnormal" rise. The object was raised to the surface parallel with it rather than at a right angle and the rise from beginning to end lasted two seconds. The data in Table I are listed in terms of successful attempts to induce rises in the tarpon by means of the manipulated objects. Each time the object is raised to the surface is considered an "attempt." The attempt is considered successful if within one second or less following the start of the rise of the model one or more tarpon rise to the surface. Rises by the fishes two or three seconds after the object had risen might also have been imitative delayed reactions but were not considered. Indeed, such rises very rarely occurred. Either the fish would respond immediately or it would not rise for a minute or more. No effort was made to differentiate between induced imitative rises that involved varying numbers of tarpon. In fact, such differentiation is very difficult if not impossible since, except in rare cases in which two or more individuals arose at exactly the same time, one cannot determine whether the rise of the tarpon following very closely that of the first animal to rise is a response to the object or to the first tarpon.

Observations were made within a ten-minute experimental period. Every second, fourth,

sixth, eighth, and tenth minute on the minute the model was raised to the surface and the reaction noted. As a control, every first, third, fifth, seventh, and ninth minute on the minute an observation was made for rises of the tarpon *without* the manipulation of an object. Each observation, control and experimental, at the two minute interval lasted only one second. In general, observations were made during two consecutive hours, or 12 experimental periods each day.

Results. The data in A of Table I indicate that all four types of objects induce imitative rises whose statistical significance compared with the controls is very high. The average rise of a tarpon in the experimental aquarium was twice in ten minutes. In a group of six animals there would be at most twelve seconds of rising in 10 × 60 or 600 seconds; thus, according to the laws of chance, rises of tarpon directly following those of models cannot very well be considered coincidental. It is seen that, of the four objects used, the wooden tarpon model is significantly most effective and the red rubber tubing is second. The degree of success in inducing imitative rises is, however, sharply limited by the physiological state of the animal. As Schlaifer & Breder (1940) demonstrated, a tarpon will not respond imitatively to the rise of another object, even if it be another normal tarpon, unless, by virtue of the fact that the oxygen obtained at the last gulp is distinctly depleted, it is in a "physiologically receptive" state which permits a rising response. The induction of an imitative rise, then, depends on the reaching of a respiratory threshold by the reacting animal. This explains why even the wooden tarpon model enjoys only 48.3% success in inducing rises. The experimental animals may rise either singly or imitatively in groups just before the model is raised to the surface. If so, even raising the object consecutively three times or more will produce no response.

The data in B of Table I demonstrate that objects manipulated so as to rise in an "abnormal" way induce few imitative rises. Comparison with the controls indicates no statistical significance.

SURFACE RISES IN BLINDED TARPON.

That the induction of imitative rises in small tarpon is a visual affair was demonstrated by Schlaifer & Breder (1940). It was found that the rise of a tarpon on one side of a transparent glass plate bisecting an aquarium could induce a rise in others on the opposite side.

Carrying this a step further, four tarpon were blinded by piercing the cornea. Blindness was ascertained by appropriate tests. Several days were allowed for recovery from the operation. Subsequently, the animals were grouped together in 40 liters of standing sea water (oxygen content—2.50 cc. per liter) in a 48-liter aquarium whose dimensions have been listed above.

In the course of several hours of observation no imitative rises occurred. The tarpon rose

TABLE I.

The Induction of Imitative Surface Rises in Small Tarpon by Various Objects.

A. Object manipulated so as to simulate a normal surface rise.

Type of Model	I Silver Wooden Tarpon	II White Spatula	III Red Rubber Tubing	IV Glass Rod	V Control ²
Total Number of Attempts ¹	176	181	176	170	703
Number of Successful Attempts	85	52	62	35	12
% of Successful Attempts	48.3	28.7	35.2	20.6	1.7

¹ Object is raised to surface for one second every two minutes in a 10-minute observation period in an attempt to induce a rise in the experimental tarpon in the aquarium.

² Observation made for one second every two minutes in the 10-minute period for rises by tarpon without manipulation of objects.

Statistical significances (number of successful attempts).*

I vs. II—.0096	I vs. III—.0210	I vs. IV—.0013	II vs. III—.4370
II vs. IV—.2898	III vs. IV—.0210	I, II, III, IV vs. V—.0000	

* Upper limit of statistical significance is set at 0.05. This is three times the probable error. 0.01 indicates good significance while a value of 0.100 or more indicates little significance. ("Student," 1925.)

B. Manipulation of object does not simulate a normal rise.†

Type of Model	I Silver Wooden Tarpon	II White Spatula	III Red Rubber Tubing	IV Glass Rod	V Control ²
Total Number of Attempts ¹	65	65	65	65	260
Number of Successful Attempts	5	5	1	2	6
% of Successful Attempts	7.7	7.7	1.5	3.1	2.3

† Object is raised to surface slowly and parallel with the surface.

¹ See ¹ above.

² See ² above.

Statistical significances (number of successful attempts).

I vs. II—None	I vs. III—.3342	I vs. IV—.4954	I vs. V—.1832	II vs. V—.2146
II vs. III—.3834	II vs. IV—.4370	III vs. IV—.5580	III vs. V—.5580	IV vs. V—.5580
I (A) vs. I (B)—.0000	II (A) vs. II (B)—.0000	III (A) vs. III (B)—.0000		
IV (A) vs. IV (B)—.0000	V (A) vs. V (B)—.4954			

individually at the same rate as did the normal animals, once every five minutes. Thus, it is apparent that in the absence of vision no imitative rise will occur; possible response to pressure stimuli does not obtain. The normal rate and type of surface rises in these blinded forms indicates that this pattern of behavior is not dependent on vision for its proper execution though imitative response by one fish to another is.

LOCOMOTOR AND RESPIRATORY ACTIVITY IN WATERS OF LOW OXYGEN CONTENT.

In previous experiments (Shlaifer & Breder, 1940) it was found that when the oxygen content of the water was increased from 2.50 cc. to 5.60 cc. per liter, the rate of respiratory activity (surface rises) decreased significantly though the locomotor activity remained the same. It becomes desirable, therefore, to determine the respiratory activity and, to a minor extent, the locomotor activity at very low oxygen levels. Small tarpon, incidentally, are relatively hardy forms and are adaptable to a variety of situations. They endure handling in the laboratory remarkably well and would be excellent laboratory material for many lines of research were they to be found more frequently and in greater abundance. They may be found both in the sea and in land-locked pools which are brackish or fresh-

water. Some of these pools have relatively little dissolved oxygen but the tarpon survive.

Materials and methods. Tarpon were placed in isolation in 7 liters of standing sea water in 8-liter rectangular battery jars whose dimensions were 20.5 cm. by 18 cm. and 21 cm. deep at the 7-liter mark. The water temperature range was 19–22 degrees C. The rates of surface rises and locomotor activity were determined for 15-minute periods. The rate of locomotor activity was determined by an observational technique which is fully described elsewhere (Shlaifer, 1938). Briefly, 3-cm. squares were ruled in red India ink on all four vertical sides of the rectangular battery jar. Using the eye of the tarpon as an anatomical landmark, the number of squares, actually cubes when projected in space, traversed in a 15-minute period was multiplied by 3 to give the results in centimeters. Since this technique is not as accurate as the simple observation of surface rises and since the experimental vessels, considering the size of the tarpon, were quite small and thus limited activity, the rate of surface rises in this set of experiments may be considered the more important feature. Oxygen content was determined by means of the permanganate modification of the Winkler method.

Results. Comparing the data in Table II with the results of Shlaifer & Breder (1940), it is seen that at the lower oxygen content the rate

of respiratory rises increases significantly and the centimeters traversed per rise decreases. The significantly lower rate of locomotor activity at the lower oxygen level may be due primarily to the distinctly smaller vessel in which the tarpon were kept in these experiments rather than to the low oxygen content. As previously mentioned, Shlaifer & Breder (1940) found that while raising the oxygen content from 2.50 to 5.60 cc. per liter in the same aquarium reduced the rate of respiratory rises it did not affect activity. At any rate, the number of surface rises increases at the lower oxygen content despite the decreased activity.

ously listed. In the first four experiments standing sea water was used; in the fifth, sixth, and seventh, running sea water. In all cases the battery jars were filled to capacity. In the standing water series, a fine wire screen cut so as to insure a tight fit was placed inside the battery jar at the 7-liter mark and in Expts. 5-7 a similarly tight-fitting wooden screen was placed at the same level. In each test the experimental tarpon was allowed a 48-hour period of acclimatization in the battery jar with access to the surface. At the end of that time the screen was put in place and the time and oxygen content noted. Each battery jar contained only one

TABLE II.

The Locomotor Activity and Respiratory Rises of Small Tarpon in Waters of Low Oxygen Content.

	Mean Oxygen Content cc./liter	Mean Locomotor Activity ¹	Mean Respiratory Rises ²	Mean cm. per Rise
A. This set of Experiments	1.02	304.0	3.6	84.4
B. Shlaifer & Breder (1940) ³	2.40	480.0	2.9	165.5

¹ Expressed in centimeters traversed per fish per 15-minute period of observation. Figure given is the mean of 80 such periods.

² Expressed in surface rises per fish per 15-minute period of observation. Figure given is the mean of 80 such periods.

³ Based on Table I (AI), Shlaifer & Breder (1940). Figures given are for an isolated tarpon in 48 liters of sea water in a 50-liter aquarium. Figures for locomotor activity and respiratory rises represent the mean of 48 15-minute observation periods.

Statistical Significances (A vs. B)

Locomotor Activity: .0003

Respiratory Rises: .007

Finally, it may be noted that if access to the surface is provided, tarpon will survive well in waters of low oxygen content and will utilize relatively more atmospheric oxygen.

SURVIVAL WITH NO ACCESS TO THE SURFACE.

The air-breathing habit in tarpon is peculiar in view of the fact that they normally inhabit fairly highly oxygenated sea water and have rather extensive gill surfaces. The value of the air-breathing habit in land-locked pools of low oxygen content in which tarpon may be found is obvious. However, its persistence in the waters of the open sea may possibly be an indication of imperfectly functioning gills, despite their size. It becomes of interest, therefore, to determine the survival time of tarpon when cut off from access to the surface and thus forced to rely on dissolved oxygen. Hora (1933) states that various air-breathing swamp fishes can be "drowned" if prevented from reaching the water surface. Das (1935) states that the air-breathing loach, *Lepidocephalus guntea*, if prevented from reaching the surface, will be asphyxiated in a little more than an hour. These fishes, however, inhabit waters in which the oxygen content is habitually low in contrast to the tarpon of the open sea.

Materials and Methods. In Expts. 1-7 of Table III, the experimental vessels were 8-liter battery jars whose dimensions have been previ-

individual at a time. A record was kept of the number of hours between the start of the experimental period and the end, which in every case was at the death of the tarpon. Oxygen determinations were made each day and at the conclusion of the experiment. The locomotor activity and surface rising of the fish were also noted but only in a general way. As controls, individual tarpon were kept in battery jars in running and standing sea water *without* being screened from the surface.

In Expts. 8-13, the experimental vessel was a 56-liter rectangular assembled aquarium with transparent glass sides whose dimensions were 60 cm. by 35 cm. and 27 cm. deep. This was kept constantly filled to capacity with running sea water. The bottom of the aquarium was covered with sand. Into this aquarium was placed a tight-fitting wire mesh screen containing three squares to the inch, at a level of 6 cm. above the bottom sand. The general procedure followed was the same as that described for the battery jar tests except that no observations were made for activity or surface rises.

Results. The data in Table III demonstrate that compelling a tarpon to rely on dissolved oxygen by screening it from the surface will result in asphyxiation in from 7 to 128 hours. Death may occur in a relatively short time even in running sea water (Expt. 5). In the standing water tests the oxygen content at the death of

the animal is high enough to maintain a tarpon indefinitely if it is permitted to respire atmospheric oxygen. There seems to be considerable individual variation in survival time. This may be a reflection of individual variations in metabolic rate. In the battery jar tests the tarpon would often make desperate and repeated futile attempts to reach the surface and, failing, would sink exhausted to the bottom, there to remain quiescent for long periods of time. In the aquarium tests, much more area was allowed for normal swimming by the fishes; also, the position of the screen, 6 cm. above the bottom, prevented exhausting and futile attempts to reach the surface. Tarpon in this aquarium, even when not screened from the surface, normally swim near the bottom so that the experimental situation in this case is, except for the screen, quite normal.

In the control tests, tarpon in battery jars with access to the surface survived indefinitely even when the standing water oxygen content was quite low.

DISCUSSION.

It is interesting to note in the model experiments that imitative rises may be induced by very crude objects differing appreciably in form and color. At the same time, a more finished wooden model is more successful than are the crude ones. The results in B of Table I indicate that movement rather than form or color is the important factor for, if the model is so manipulated that the normal rise of a tarpon is not simulated, there is no significant induced imitation, even with the wooden model. Nevertheless, a properly manipulated silver wooden model is more successful than are properly manipulated objects that are distinctly cruder models. Apparently, then, form and/or color may also be involved but only in a minor supplementary way. Possibly at a distance of several inches or more from the reacting tarpon the type of wooden model used was more visible than were the other objects. Using this imitative rising reaction, it may be

TABLE III.

Effect of Prevention of Surface Rises on the Survival of Small Tarpon.

Experiment No.	Water	Oxygen Content*	Survival in Hours	Remarks
1 ¹	Standing	3.39-2.20-1.60	53	Periods of great activity and attempts to reach surface followed by periods of quiescence.
2 ¹	Standing	3.47-2.98-2.70-2.52	71	"
3 ¹	Standing	4.15-3.20-1.68	51	"
4 ¹	Standing	4.07-1.92	11	Tarpon very active—many attempts to reach surface.
5 ¹	Running	4.86	7	Tarpon very active.
6 ¹	Running	5.58	72	Activity and rises of fish increase markedly one day before death.
7 ¹	Running	5.58	128	
8 ²	Running	5.58	32	
9 ²	Running	5.58	115	
10 ²	Running	5.58	125	
11 ²	Running	5.58	24	
12 ²	Running	5.58	34	
13 ²	Running	5.58	46	

* In the standing water experiments, the oxygen content is given day by day in cc. per liter. The final figure represents the oxygen content of the medium at the death of the experimental animal. In the running water series, the figures given represent the average oxygen content in cc. per liter day by day.

¹ Experimental vessel is an 8-liter battery jar.

² Experimental vessel is a 56-liter aquarium.

In several cases attempts were made to revive tarpon which, after a long period of time, were near asphyxiation and lay on their sides. They were permitted to come in contact with the surface but evidently were too far gone, for they soon died. In one case, however, three blinded tarpon, which when screened from the surface in standing water in a battery jar soon approached exhaustion and asphyxiation, did recover when the screen was removed after one hour. In that time, unlike normal tarpon, they kept rising almost continually in attempts to penetrate a screen which they could feel but could not see and within 40 minutes lay on their sides. Das (1935) reports that the air-breathing loach will recover from partial asphyxiation if permitted to rise to the surface after being kept under a screen.

possible, by employing a great variety of objects differing in form and color but manipulated normally, to obtain data which may be of significance in obtaining a measure of the visual acuity of tarpon. The data already obtained, showing as they do only a slight though real difference between a good and a crude model in their relative success at inducing rises, tend to indicate that such experiments would require considerable data to have any significance.

It has been seen that preventing a tarpon from utilizing atmospheric oxygen will eventually be fatal, even in highly oxygenated water. Hence, there is no question of the survival value of the surface rise pattern of behavior in these forms. In contrast to the work of Hora (1933) and Das

(1935), the asphyxiation of tarpon under screens is a very slow process. Undoubtedly there is interesting material here for exhaustive physiological studies.

It is quite difficult to evaluate the pattern of imitation in surface rising in a group of tarpon. Schlaifer & Breder (1940) have shown that imitation will not occur, apparently, until a respiratory threshold is reached. An isolated tarpon will rise periodically in response to physiological need and over a period of time not much more frequently if it is in a group. It is difficult, at least at this time, to attribute any adaptive value to this imitative behavior which might be termed "social respiratory facilitation."

SUMMARY.

1. Imitative air-gulping surface rises in small

tarpon may be induced by relatively crude models if they are manipulated so as to simulate the normal surface rise of this form. A relatively more life-like wooden tarpon model is more successful than are the cruder objects. No significant success is attained with any model if its manipulated rise differs appreciably from the normal.

2. The imitative pattern is based on visual stimuli rather than on differential pressure stimuli. Blinded tarpon never rise imitatively.

3. At distinctly low oxygen levels, the rate of respiratory rises increases but if access to the surface and hence to atmospheric oxygen is maintained the tarpon survive.

4. Tarpon when prevented from utilizing atmospheric oxygen succumb in 7 to 128 hours even in highly oxygenated running sea water.

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12.

Notes on Mexican Snakes of the Genus *Trimeresurus*.

HOBART M. SMITH.

A review of the species of *Trimeresurus* now known from Mexico has revealed some confusion in the literature, to which I personally have contributed to some extent. In addition to correction of some of these errors, the present paper presents two forms new to the fauna of Mexico, names a population previously associated with *lansbergii*, and diagnoses in a key the eleven forms definitely known to occur in the country. It should be noted that *schlegelii*, treated by Terron (*Anal. Inst. Biol. Mex.*, vol. 1, 1930, pp. 196-7, fig. 7) as a member of the Mexican fauna (without locality), has never been reported nearer Mexico than the "Guatemala" record of Boulenger (*Cat. Snakes*, vol. 3, 1896, p. 567). Its existence in the country is problematical.

I am much indebted to Dr. E. R. Dunn, who has very generously checked the types of *brachystoma* and made a number of valuable additions to the paper. The study has been completed, and a portion of the material on which it is based has been collected, during tenure of a Walter Rathbone Bacon Traveling Scholarship.

Trimeresurus godmani (Günther).

Bothreischis godmani Günther, *Ann. Mag. Nat. Hist.*, ser. 3, vol. 12, 1863, pp. 364-365, pl. 6, fig. G (Totonicapam, Guatemala).

Bothrops godmani Martín del Campo, *Anal. Inst. Biol. Mex.*, vol. 9, 1938, p. 229, fig. 2.

One specimen from Santa Rosa, near Comitán, Chiapas, was reported by Martín del Campo. It has 142 ventrals, 33 caudals, dorsals in 21 rows, 9-10 supralabials.

I have examined six specimens, all from Guatemala and Costa Rica.

Trimeresurus barbouri (Dunn).

Lachesis barbouri Dunn, *Proc. Biol. Soc. Wash.*, vol. 32, 1919, pp. 213-214 (Omitlilte, Guerrero).

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Agkistrodon browni Shreve, *Copeia*, 1938, p. 9 (Omitlilte, Guerrero).

This diminutive species is known only from three specimens collected at the type locality, of which I have examined one, the type of *barbouri* (U. S. N. M. 46347).

I cannot see that *browni* is different from *barbouri*. The apparent difference in ventral counts of the types (134, *browni*; 154, *barbouri*) is not real, since the *browni* type is a male, and the *barbouri* type a female, the ventrals of which should have been written 145 (I count 144 to 147, according to the number of smaller anterior scales counted as ventrals). The only remaining apparent difference is in the presence of larger head shields, with distinct prefrontals, frontal and parietal in *browni*. I believe the size of the dorsal head scales varies in this species, as it certainly does in *godmani*, to which the Omitlilte species is related. In six specimens of *godmani* several intermediate stages between more or less uniform, small scales and the presence of distinct frontals and parietals are shown. Since the type of *barbouri* has small but distinguishable prefrontals, and since the presence or absence (and size when present) of the frontal and parietals is variable in a closely related species, I believe there is no reasonable doubt that *browni* and *barbouri* are synonymous.

Trimeresurus bicolor (Bocourt).

Bothrops bicolor Bocourt, *Ann. Sci. Nat.*, ser. 5, vol. 10, 1868, p. 201 (San Agustín, Guatemala).

The only specimen examined is one in the National Museum (No. 46511), from Chicharras, Chiapas. It is a small female with 168 ventrals, 48+ caudals (tail tip missing), 10-11 supralabials, 12-12 infralabials, and 10 scales between the narrow supraoculars; second supralabial enters pit on one side, does not on other.

The species is closely related to *lateralis* Peters (1852), of Costa Rica, which has larger head scales (7 or 8 between supraoculars), a yellow line along outer row of scales and sometimes short black-and-yellow cross-bars (*vide* Boulenger).

ger). There is no difference between the two in number of labials (the single specimen examined of *lateralis* has ten), nor in exclusion of the second supralabial from the pit (see above).

***Trimeresurus nigroviridis aurifer* (Salvin).**

Thamnocenchris aurifer Salvin, *Proc. Zool. Soc. London*, 1860, p. 459, pl. 32, fig. 1 (Cobán, Guatemala).

Bothrops nigroviridis aurifera Barbour and Loveridge, *Bull. Antiv. Inst.*, vol. 3, 1929, pp. 1-3; Martín del Campo, *Anal. Inst. Biol. Mex.*, vol. 9, 1938, pp. 228-229, fig. 1.

This species was first reported from Mexico by Martín del Campo, who cites a specimen from Santa Rosa, near Comitán, Chiapas. It has 159 ventrals, 44 caudals (lower than other *aurifer* reported in the literature), 9-10 supralabials, scales in 19 rows. I have seen no specimens.

***Trimeresurus atrox* (Linnaeus).**

Coluber atrox Linnaeus, *Syst. Nat.*, 1758, p. 22 (Asia, erroneous).

Trimeresurus atrox Schmidt and Andrews, *Zool. Ser. Field Mus. Nat. Hist.*, vol. 20, 1936, p. 182.

Specimens of this species have been taken as far north as Valles, San Luis Potosí (Martín del Campo, *loc. cit.*, records it from Tamaulipas); it occurs throughout the Atlantic coastal region south of this point, and also along the Pacific coast in southeastern Chiapas. Boulenger records it from farther north on the Pacific coast, from Atoyac, Guerrero (*Cat. Snakes*, vol. 3, 1896, p. 536).

The nineteen Mexican specimens examined differ from South American specimens in the character of the carinae of the median scales, as pointed out by Boulenger (*op. cit.*, pp. 535-539). I can find no other difference.

***Trimeresurus nummifer nummifer* (Rüppell).**

Atropos nummifer Rüppell, *Verz. Senck. Mus., Amph.*, 1845, p. 21 (Mexico).

Trimeresurus nummifer nummifer Dunn, *Proc. Biol. Soc. Wash.*, vol. 52, 1939, pp. 165-166.

Specimens are known from central Veracruz along Atlantic slopes into Central America, and on Pacific slopes in southeastern Chiapas. The species is rarer than *atrox*, and is apparently confined to hilly regions, while *atrox* is more widespread and ranges from hills to plains. I have examined thirteen Mexican specimens.

***Trimeresurus nasutus* (Bocourt).**

Bothrops nasutus Bocourt, *Ann. Sci. Nat.*, ser. 5, vol. 10, 1868, p. 202 (Panzos, Río Polochic, Guatemala).

One specimen (U. S. N. M. 110415) is known from the Mexico-Guatemala border, bearing the locality data Piedras Negras, Guatemala. Dr.

E. R. Dunn tells me that there is one in the Museum of the Philadelphia Academy of Natural Sciences, labelled Veracruz (No. 4873, collected by Rev. H. F. Heyde). This is quite different from *dunni* and *yucatanicus*, all of which are related; *nasutus* has a much higher rostral and a different arrangement of the preocular and subocular scales. Two specimens have been examined, the other from Panamá.

***Trimeresurus dunni* Hartweg & Oliver.**

Trimeresurus dunni Hartweg & Oliver, *Occ. Papers Mus. Zool. Univ. Mich.*, no. 390, 1938, pp. 6-7, pl. 1 (Tehuantepec, Oaxaca).

Known from the semi-arid Pacific slopes of the Isthmus of Tehuantepec (seventeen specimens examined).

The definition of this species by Hartweg & Oliver has greatly clarified the situation with respect to *lansbergii*, with which the Tehuantepec as well as Yucatán specimens were previously associated. Prior to their action, three separate populations of *lansbergii* were apparent: one in northern South America and in Panamá; one in Oaxaca; and the third in Yucatán. Between Mexico and Panamá no specimens related to *lansbergii* are known. All of this group from that intermediate area are referable either to *ophryomegas* or to *nasutus* (*c. f.* Amaral, *Bull. Antiv. Inst.*, vol. 3, 1929, pp. 19-27).¹

The isolated group in Yucatán is not the same as *dunni*, nor can it be referred to typical *lansbergii* of South America. I propose the name

***Trimeresurus yucatanicus* sp. nov.**

Holotype. U. S. National Museum 46571, female, from Chichen Itza, Yucatán, collected by Nelson & Goldman, February, 1901. *Paratypes*. Field Museum of Natural History No. 504, Yucatán, and No. 20621, Chichen Itza, Yucatán.

Diagnosis. Snout turned up in front; rostral no more than one and one-half times as high as wide; scale rows 21 posteriorly; two lower preoculars subequal, both excluded from orbit; two large scutes on top of head bordering internasals and canthals, nearly meeting medially; loreal square; caudals 32 to 41 in females; bands on body single.

Description of Holotype. Rostral very high, its length (2.6 mm.) somewhat greater than greatest width (2.2 mm.), twice width of upper part (1.3 mm.); internasals elongate, elevated, in contact medially; one canthal; preocular encroaching on dorsal surface between canthal and supraocular; five or six scales between supraoculars; dorsal head scales keeled; a large scale, as large as canthal, bordering internasal medially, in contact with canthal, separated from its mate by one scale; ten supralabials; first labial in contact with anterior section of nasal, separated from posterior section by a very small scale and a small, wedge-

¹ *Trimeresurus lansbergii annectens* Schmidt is certainly referable to *ophryomegas*, of which it may be a subspecies.

shaped protrusion from anterior section; scale between second labial and posterior section of nasal quite small; one row of small scales between labials and border of pit; two tiny scales between nasal and border of pit; loreal moderately large, nearly square; one moderately large scale between lower preocular and third labial; one row of scales between subocular and labials; subocular single, very elongate; one very large upper preocular, about twice as large as loreal, somewhat smaller than canthal; two lower preoculars, both separated from labial border, both small; median preocular partially fused with an elongate scale bordering edge of pit; edge of supraocular thin; edge of canthal somewhat raised, rather sharp anteriorly; edge of preocular not keeled, rounded. Eleven or twelve infralabials; first infralabials in contact with each other behind mental; three labials in contact with chinshields; one large anterior pair of chinshields, about as long as combined width; this followed by two small pairs of scales.

Dorsals in 27-27-21 rows; 148 ventrals; 32 caudals, entire; anal entire. Total length 254 mm.; tail 26 mm.

Specimen badly faded. Ground color light gray, stippled; seventeen somewhat staggered, darker cross bands, split on middorsal line; blotches covering about six scale lengths, separated by light areas covering about four scale lengths; anterior and posterior edges of cross bands black, narrowly light-edged; some blotches faintly divided by a very slightly lighter, transverse area; the dark borders terminating about four scale rows lateral to vertebral row; blotches faintly interrupted at this point, below which are two rounded spots of same color as blotches, separated from each other, and more or less fused with the blotches; belly heavily stippled; a few light marks in labial region.

Remarks. So far as now known, the only specimens of *Trimeresurus* from areas north of Panamá having a rostral similar to that of *lansbergii* are those from the Tehuantepec area which have been described by Hartweg & Oliver as *dunni*, and the present three specimens from Yucatán. The latter three are not the same as *dunni*, since the bands are not paired; the scale rows usually more numerous in front of anus (21 at anus in one out of 27 *dunni*, 21 in all three *yucatanicus*); two lower preoculars small, subequal, excluded from orbit (middle larger, entering orbit in *dunni*).

From *lansbergii* itself the present species apparently differs in having 21 scale rows posteriorly, usually more numerous subcaudals (28 to 33 in females, 31 to 36 in males of *lansbergii*; 32 to 41 in females of *yucatanicus*); two relatively large scutes bordering internasals and canthals, nearly meeting each other medially (no such scales in *lansbergii*, apparently); loreal square (usually narrow, about twice as long as broad in *lansbergii*).

In 1859 Cope described a form called *brachystoma* (*Proc. Acad. Nat. Sci. Phila.*, 1859, p. 339).

The series on which this name was based is now in the collections of the Philadelphia Academy of Natural Sciences, and consists of four specimens (of which No. 7043 is the type), all collected by Mr. Cuming at unknown localities. All four have 19 scale rows posteriorly, elongate loreals and bands single, and accordingly agree with the characters of *lansbergii*. They probably were secured in South America, as Dr. Dunn states that numerous other specimens collected by Cuming are in the Academy collections, all apparently from South America.

Trimeresurus undulatus (Jan).

Trigonocephalus (Atropos) undulatus Jan, *Rev. Mag. Zool.*, 1859, p. 157 (Mexico).

Specimens in the National Museum are from Orizaba, Veracruz (No. 6319); Omilteme, Guerrero (Nos. 46345-6, 46348); and Oaxaca, Oaxaca (No. 46466). The species has also been reported from the state of Hidalgo (Martín del Campo, *op. cit.*, p. 14).

Trimeresurus melanurus Müller.

Trimeresurus melanurus Müller, *Mitt. Zool. Mus. Berlin*, vol. 11, pt. 1, 1923, pp. 92-93 (Mexico).

Trimeresurus garciai Smith, *Proc. Biol. Soc. Wash.*, vol. 53, 1940, pp. 62-64, fig. 2 (Cacaloapam, Puebla).

This species is known only from the desert region about Tehuacán, Puebla. Its divided caudals and the horn-like supraocular distinguish it from all other species in Mexico. Three specimens have been examined.

KEY TO MEXICAN TRIMERESURUS

1. Supraocular produced as a soft, horn-like scute 2
Supraocular flat 3
2. Subcaudals entire *melanurus*
Subcaudals divided *undulatus*
3. Snout produced, turned up 4
Snout not noticeably turned up 6
4. Rostral about twice as high as wide *nasutus*
Rostral no more than one and one-half times as high as wide 5
5. Bands on body distinctly paired; two lower preoculars small, subequal, excluded from border of orbit; scale rows 21 in front of anus
yucatanicus
Bands on body paired, each half well defined and usually separated medially from its mate; middle preocular considerably larger than lower, broadly in contact with border of orbit; scale rows usually 19 in front of anus
dunni
6. Subcaudals double *atrox*
Subcaudals single 7
7. Scales in 23 rows or more; size large
nummifer nummifer
Scales in 21 rows or less; size smaller 8
8. Width of a supraocular about half distance between supraoculars; subcaudals 22 to 34; brown; terrestrial 9
Width of a supraocular one third distance between supraoculars, or less; subcaudals 44 to 67; green; arboreal 10

- 9. Scales in 21 rows; upper preocular large, forming part of canthal ridge; loreal small, excluded from canthal ridge, not in contact with supraocular *godmani*
- 10. Head scales smooth; scales in 19 rows forming part of canthal ridge, in contact with supraocular *barbouri*
- Head scales keeled; scales in 21 rows *nigroviridis aurifer*
- Head scales keeled; scales in 21 rows *bicolor*

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13.

The Life History and Bionomics of the Trematode, *Zygocotyle lunata* (Paramphistomidae).

CHARLES H. WILLEY

Department of Biology, University College of Arts and Pure Science, New York University

(Plates I-IV).

Zygocotyle lunata belongs in the family Paramphistomidae Fiscoeder, 1901. Diesing (1836) described the species from material collected by Natterer, in Brazil, from the ceca of several species of water birds and from the cecum of the deer, *Cervus dichotomus*, and named it *Amphistoma lunatum*. Fiscoeder (1903) redescribed the species from 4 whole mounts of Diesing's original material in the Vienna Museum. Stunkard (1917) erected the genus *Zygocotyle*, to contain *A. lunatum* and a new species, *Z. ceratosa*, described by him from the intestine of a duck, *Anas platyrhynchos*, from Nebraska. Price (1928) showed that *Z. ceratosa* was specifically identical with *Z. lunata*.

The host relationships of the genus *Zygocotyle* are of considerable interest. Diesing (1836) described it from the cecum of a deer, *Cervus dichotomus*, and also from the ceca of the birds, *Anas melanotos*, *A. epecuri* and *Himantopus wilsonii*. Fiscoeder (1903), after an examination of 4 of Diesing's specimens, concluded that the record of the ruminant *Cervus dichotomus* as a host of this form was probably due to an error in labelling. As pointed out by Price (1928), Dujardin (1845) and Diesing (1850) had earlier arrived at the same conclusion because of the wide difference in hosts. The suspicion of error persisted until the occurrence of *Zygocotyle* in both birds and mammals was definitely shown by Price (1928) who studied specimens of an amphistome reported by Hall (1927) from the cecum of a cow, *Bos taurus*, and identified them as *Zygocotyle lunata*, thus confirming and validating Diesing's original record. In the present study, infections with *Z. lunata* have been experimentally produced in the sheep, *Ovis aries*, and in the rat, *Mus norvegicus*, as well as in ducks. Thus a rodent as well as another ruminant is here added to the list of mammalian hosts. All the rats exposed (more than 60) became infected.

Several years ago the writer (1930, 1936) described a new species of cercaria, *C. poconensis*, from *Helisoma antrosom* collected near Henryville, Pennsylvania. Life history studies with the

material in an attempt to identify the adult stage failed, and the investigation had to be abandoned because the infestation was no longer present in the snails from that region. In September, 1937, one specimen of *Helisoma antrosom* from Prospect Park Lake in New York showed an infestation with *Cercaria poconensis*, and subsequent collection of 450 snails from the same lake during October yielded 3 additional infections. Cercariae from these 4 naturally infested snails encysted in dishes in the laboratory and furnished the material for feeding experiments. Metacercariae fed to rats, ducks and sheep developed into adults of *Zygocotyle lunata* in the ceca of these hosts. Eggs, collected from feces, developed in the laboratory and young laboratory-raised snails of the species *Helisoma antrosom*, on exposure to the hatched miracidia, became infected, yielding the sporocyst, redial and cercarial stages, thus demonstrating experimentally the complete life cycle. Preliminary reports were presented in abstract form (Willey, 1937, 1938).

Gower (1938) in a study of trematodes infesting wild ducks in Michigan obtained an experimental infestation in a half-grown mallard duck of 46 immature specimens of *Zygocotyle lunata* with metacercariae from a naturally infected snail identified as *Helisoma trivolvis*.

Much progress has been made in recent years in the demonstration of North American trematode life cycles. Most of the advances have been made, however, in groups other than the amphistomes. Life cycle studies in this group, with the exception of that of Bennett (1936) on *Cotylphoron cotylophorum*, are mostly incomplete, since they lack one or more stages or fail to provide experimental proof in support of conclusions based on morphological similarity.

The demonstration of a complete life cycle requires that all stages be described and obtained experimentally. The studies may begin with any step in the sequence. In trematode studies either of two modes of attack are commonly employed. One may start with the cercarial stage,

obtained from naturally infected snails, and expose various possible hosts to it or to the metacercaria, if the cercaria encysts in the open. Such experimental hosts must be known to be free from previous infection which might be confused with the experimental one. Frequently, the structure and activities of the cercariae together with information on the fauna occurring in the same environment will give some indication of the next host. Similarly, one might start with the adult stage of the trematode in the final host. Eggs are then collected and permitted to develop and various species of snails are then exposed to the hatched miracidia. Successful infestation provides the asexual stages in the snail. In either method, the cycle is followed back to the starting point.

In the present study the investigation began with 4 naturally infected snails and, as described later, infection was obtained in the final hosts. The rats, all of which became infected, had been laboratory-raised for many generations and the ducks were known to be previously uninfected, because none in a control series of ducks, being used for other experiments, ever showed any eggs or specimens of *Zygocotyle lunata*, while all the experimentally-fed ducks became infected with the species. The complete life cycle was passed through several times in the laboratory. No further collections of naturally infected snails were made since ample material was available in the laboratory throughout the investigation. The life cycle as here presented begins with a description of the eggs obtained from experimentally infected hosts, after which the succeeding generations are considered in the order of their occurrence. The materials and methods employed with the various stages are described separately for each stage.

EGG.

The eggs of *Zygocotyle lunata* examined alive from feces or from living unstained worms are colorless. The shell is very delicate and as studied in optical sections under high magnification, it does not exceed 1.5μ in thickness. If pushed about with a blunt needle the eggs are easily dented and burst readily with rough handling (Fig. 1). They are broadly ovoid and show little variation in shape (Fig. 2). The slightly attenuated end bears an operculum measuring from 28μ to 31μ in diameter. The edges of the operculum are irregularly notched and these notches interdigitate closely with similar irregular notches on the edge of the shell. A slight excrescence, from 10 to 15μ in diameter, occurs on the shells of all the eggs at the broad end. The freshly deposited egg contains a large number of granular yolk masses suspended in a transparent fluid; and the ovum, measuring from 20μ to 25μ in diameter, still unsegmented, lies embedded between the vitelline masses in the opercular half of the egg (Fig. 1).

Eggs of *Z. lunata* vary much in size. Several hundred eggs collected from feces of ducks and rats infected with newly matured worms, as well

as eggs from infestations of more than a year's duration, were measured. Eggs from feces of a duck and of a rat, each of which had been infested from a single feeding of metacercariae 13 months previously, show no significant difference in size. The eggs from the duck varied in length from 132μ to 152μ and those from the rat from 132μ to 158μ . Width varied in eggs of the duck parasites from 92μ to 102μ and in those from the rat from 89μ to 102μ . The average size of 38 eggs deposited by worms in the duck was 142μ by 98μ , while that of the 38 eggs from the rat feces measured 141μ by 96μ . The variation in size of eggs from these 13-month-old worms was 26μ in length and 13μ in width. Bennett (1936) showed a similar size range (30μ in length and 10μ in width) in eggs of *Cotylphoron cotylphorum*.

Fifty-six eggs of young, newly mature *Z. lunata* collected in a fecal sample from a duck experimentally infected 48 days before, varied in length from 132μ to 152μ and in width from 99μ to 102μ , the average measurements for the group being 145μ by 99.5μ . Similarly, 54 eggs of young, newly mature worms collected in a fecal sample from a rat infected 49 days before, varied in length from 132μ to 158μ and in width from 92μ to 105μ , the average measurements for this group being 141μ by 98.8μ . As with eggs from older infestations, no significant difference in size appears between eggs of worms in the 2 hosts. Further, it may be seen that the size range is the same for eggs from new and old infestations. While in the eggs measured in these series, the average length and width of eggs from young infestations slightly exceed those of older infestations, the difference is not significant.

Thirty eggs measured in stained whole mounts of newly matured worms varied from 132μ by 86μ to 152μ by 99μ , the average being 143μ by 91μ . While the average width (91μ) of these eggs in stained and mounted young specimens is about 5μ less than that of living eggs from older worms, the extremes in both dimensions are practically the same in eggs from fixed and stained specimens of all ages as in eggs from feces. The average obtained for all eggs of *Z. lunata* measured in the present investigation is 142μ in length and 96μ in width.

Price (1928) tabulated measurements of *Z. lunata* from different hosts and showed a remarkably wide variation in egg size. The eggs measured by Price and others from 7 host species vary from 124 to 153μ in length and from 72 to 96μ in width, the extreme range of variation being 29μ in length and 24μ in width. This range is somewhat wider than in the present study. All of the material used by the present author for egg measurements was obtained from experimental infestations with metacercariae from 2 naturally infected snails collected from the same small pond. The hosts yielding the specimens of *Z. lunata* for egg measurements as tabulated by Price were natural infections studied under different conditions by different workers and collected from widely separated parts of

North and South America. The differences in egg size may possibly be explained by this difference in source of material. With regard to egg size in amphistomes, it is difficult to draw any conclusion of value other than that egg size is of little importance in classification within a family.

MIRACIDIUM.

Development. Studies on development of the miracidium of *Zygocotyle lunata* were carried out on eggs obtained from feces of experimentally infected ducks and rats. All eggs observed were in the one-cell stage at the time of deposition. Much difficulty, due to bacteria and molds, was experienced in obtaining successful development of the ovum. The best results were obtained by keeping the eggs in petri dishes and changing the water twice daily. Immediately after collection from feces, the eggs were washed through 8 or 10 changes of tap water. Other methods involving (1) the use of sterile water, (2) gentle mechanical agitation and (3) a method by which drops of water fell continuously into dishes of water containing eggs were all found to be unsatisfactory. Eggs allowed to develop at a constant temperature of 25° C. in an incubator gave somewhat better results than those exposed to varying temperatures in the laboratory. By transferring the eggs twice daily with a micropipette to dishes of clean water, about 50 to 60 per cent of the embryos hatched and even then it was necessary to clean the mold from some of them with dissecting needles before they would hatch. In no case was it possible to obtain complete development without some mold forming on the eggs.

Bennett (1936) described in considerable detail the developmental stages of the miracidia of *Cotylophoron cotylophorum* and found a remarkable similarity in the sequence of organ development between that species and development in other species of trematodes as described by Thomas (1883), Looss (1892, 1896), Ortmann (1908), Johnson (1920), Stunkard (1923), Barlow (1925), Ishii (1934) and Suzuki (1931). Bennett (1936) says, "The development of the miracidium as described here coincides in practically every detail with the development of the miracidia described by the workers mentioned earlier in this discussion. This result points to the conclusion that the chronological sequence of organ development in trematode miracidia is essentially the same."

In view of Bennett's complete account of development in *C. cotylophorum*, a closely related amphistome, and the similarity manifested in the developmental history of miracidia in trematodes generally, detailed observations on the sequence of organ development are not recorded here for *Zygocotyle lunata*. However, all stages were observed in the course of the present study, using living material in hanging drops, and the process in *Z. lunata* follows very closely that described for *C. cotylophorum*.

The time required for development and hatching varies, the minimum time being 19 days and

the maximum 40 days in the material of *Z. lunata* studied under laboratory conditions. Between these extremes the rate of development varied with the season of the year, more time being required during the colder than in the warmer months. Most of the eggs were embryonated at room temperature, and during the winter the room was much cooler during both day and night than in the summer. Temperature is probably the factor controlling speed of development, but controlled experiments using different temperatures at the same season of the year were not conducted. Table 1 shows the relation between time required for development and season of the year. In each case the time noted is that time elapsed from deposition of the eggs until emergence of the first miracidium in the given batch of eggs. In all the cultures, hatching was spread out over periods of 4 days or longer, indicating individual differences either in maturity of the eggs at deposition or in developmental rate. In a culture of developing miracidia of *Z. lunata*, most of the embryos are at about the same stage of organ formation but some develop more slowly than others in the same dish.

TABLE 1.

Seasonal variation in developmental rate of miracidia of *Zygocotyle lunata*.

Date of deposition of eggs	Date of hatching of first miracidia	Days elapsed
Dec. 2, 1937	Jan. 10, 1938	39
Dec. 4, 1937	Jan. 13, 1938	40
Dec. 16, 1937	Jan. 18, 1938	33
Jan. 22, 1938	Feb. 16, 1938	25
Feb. 2, 1938	Feb. 27, 1938	25
Feb. 23, 1938	March 21, 1938	26
March 5, 1938	March 27, 1938	22
March 14, 1938	April 7, 1938	24
April 15, 1938	May 8, 1938	23
May 25, 1938	June 15, 1938	21
June 9, 1938	June 30, 1938	21
June 10, 1939	June 29, 1939	19
July 22, 1939	Aug. 11, 1939	20
July 25, 1939	Aug. 16, 1939	22
Aug. 12, 1938	Aug. 31, 1938	19
Sept. 1, 1938	Sept. 22, 1938	21
Sept. 4, 1939	Oct. 4, 1939	30
Oct. 15, 1938	Nov. 9, 1938	25
Oct. 29, 1938	Dec. 1, 1938	33
Nov. 19, 1938	Dec. 19, 1938	30

Figures 3, 4 and 5 are photomicrographs of embryos of *Z. lunata* at 13, 18 and 21 days of development respectively, from a culture in which the first miracidium hatched in 21 days. In the 13-day stage the embryo is 135 μ to 140 μ long and is slipper-shaped, occupying the entire length of the egg. The yolk masses have begun to increase in size and decrease in number by a process which suggests a coalescence of the contents of adjacent masses. Very little movement of the embryo could be observed at this stage. Cilia are present but were not seen to move. The anlage of the "gut" is well established and flame cells are only occasionally seen. They have large nuclei at the base of a small tuft of cilia which measures approximately 6 μ \times 3 μ . The

nuclei are visible only after the embryonated egg is somewhat compressed and only after the embryo reaches a moribund state. No vitelline membrane could be discerned and from this stage on, the embryo occupies the entire length of the egg. No space is left at either end and the granular mass called a "mucoid plug" by Barlow (1925) and described in detail by Bennett (1936) for *Cotylophoron cotylophorum*, is entirely absent at all stages in eggs of *Zygocotyle lunata*. In *Z. lunata* numerous refractive, spherical masses are usually to be seen lying outside the embryo (Figs. 3, 4). They are left behind when the miracidium hatches and may be excretory in nature.

An 18-day old embryo (Fig. 4) shows practically all the body organs well developed and exhibits much movement, shifting backward and forward and constricting the body transversely at the junctions of the rows of epidermal cells. The yolk masses are now few in number and very large. Increase in length and width has necessitated a folding forward of the posterior fourth of the body, which becomes J-shaped. The nerve mass is well developed as a concentrated, somewhat spindle-shaped band of small cells near the posterior limit of the anterior third of the embryo. The cilia are active, beating spasmodically every few minutes. The flame cells are large ($12\ \mu$ by $5.5\ \mu$) and actively beating, but no collecting tubules were observed at this stage. Germ cells are well-defined in the posterior third of the body.

The embryo of 21 days development shown in Fig. 5 would not be ready to hatch before 24 to 48 hours although some others in the same culture dish were hatching. Several yolk masses are still present and appear to be partitioning off the part of the egg not occupied by the embryo. These apparent divisions always disappear completely before hatching occurs. At this stage there is much constricting of the body as a whole and of the "gut" which is half as long as the body. Granules suspended in a fluid in the "gut" shift back and forth due to apparent waves of contraction in the wall of the "gut" (Fig. 5). The cilia beat slowly from time to time. Anteriorly, the apical papilla presses closely against the operculum. The embryo maintains a J-shaped form and the position shown in Fig. 5 until the time of hatching.

Hatching. With the disappearance of all the yolk masses the content of the egg is a continuous fluid in which the miracidium lies free. It shifts back and forth rapidly and the cilia begin to beat violently. One gets the impression at first that the apical papilla batters against the operculum to open it by mechanical pressure. More gentle movements of the same nature take place during the last 2 days before hatching. In the majority of cases the miracidium emerges without having turned around in the egg and this appears to be the normal procedure. Shortly before hatching, many large refractive granules from $4\ \mu$ to $10\ \mu$ in diameter, and clusters of smaller spherules, remain more or less stationary within the egg shell, but when the miracidium is ready

to emerge, the violent ciliary action causes the granules to be swirled rapidly about with the fluid. Normally the operculum opens within one hour after this violent activity starts and emergence of the larva requires from a few seconds to fifteen minutes. Those which require the longer time to get out of the egg shell are apparently abnormal in some way or are injured in emerging, since they usually do not swim far and soon die. The diameter of the operculum is only about half the width of the miracidium which must constrict appreciably as it passes through. During the entire process of emergence the cilia are beating very rapidly.

Some miracidia turn around again and again in the shell at hatching time. In such eggs, opening of the operculum appears to be delayed. Some of these larvae emerge normally when the operculum does finally open, but in other eggs the operculum opens only after the miracidium has exhausted itself by its activity and may emerge only half way and die in that position. Some swim around incessantly within the egg shell for as long as 7 hours and die there.

It seems significant that in many cases where the larva fails to emerge readily, it turns about actively in the egg and applies the apical papilla against the two ends of the shell with equal frequency, apparently trying to find an opening at first one end and then the other. In two such eggs observed in hanging drops, the operculum opened while the apical papilla was directed toward the opposite end of the egg. Within a few seconds the larva turned and emerged rather slowly through the opening but swam away vigorously when free from the shell. This observation seems to indicate that glandular secretions are produced at hatching time which effect the opening of the operculum, and that mechanical pressure by the apical papilla is probably not the direct cause for its removal. Normal larvae develop in a position adapted to straight-forward emergence. No embryos were observed developing in a reversed position.

A remarkable periodicity exists in the time of day that miracidia of *Z. lunata* hatch. In observations on hundreds of mature miracidia in many different culture dishes at all hours of the day and night, very few were observed to hatch or to have hatched before 5:00 P.M. and no miracidia were ever found swimming in the cultures in the morning after 9:00 A.M. The majority hatched between 10:00 P.M. and 2:00 A.M. In many cases, mature miracidia were observed in eggs until about midnight or later in order to study the hatching procedure. Often none would hatch, but almost invariably some of them would be found either moving very feebly or dead in the dish at 9:00 in the morning, having hatched during the early morning hours. Those which had not hatched during the night usually remained in the egg shell until the following night, when more would emerge. Darkness does not seem to be the controlling factor, for just as many larvae hatch in a culture dish placed under the strong beam of a microscope

lamp as in dishes covered with black paper. Attempts to induce consistent hatching of miracidia for study during the day, by the stimuli of light and darkness, were entirely unsuccessful. Agitation with dissecting needles of eggs containing mature miracidia sometimes causes the operculum to open, probably by mechanical injury to the egg shell, but most if not all individuals induced to emerge in this fashion are abnormal and die without getting very far away from the opened shell.

The miracidium swims very rapidly, usually in straight lines for considerable distances before darting off suddenly in a new direction. In syracuse watch glasses they may be seen either swimming back and forth across the dish or following around the edge in either direction. When no snail is in the dish the movements of the larva seem to be entirely at random. No phototropism was observed and they do not show any tendency to concentrate in any one place or in any way to influence each other. They swim incessantly for varying periods up to 7 hours, after which they slow down, sometimes swimming for a time in narrow circles, and die on the bottom of the dish in a somewhat bloated condition and contracted in length. As described in a later section of the present paper, they usually enter the snail host within two hours.

MORPHOLOGY OF THE MATURE MIRACIDIUM.

Studies on the morphology of mature miracidia of *Zygocotyle lunata* were conducted, using unstained living and moribund individuals in hanging drops, silver impregnated specimens prepared according to the method described by Lynch (1933), and specimens stained intravitally with neutral red. When swimming, the miracidium is elongated with sides almost parallel. Anteriorly it is cone-shaped and terminates in a protrusible cap called by some authors the apical papilla. The posterior end is bluntly rounded. Moribund specimens and those which may be momentarily quiescent contract appreciably in length and become broader. The anterior, coniform region and apical papilla may be retracted and the specimen becomes much expanded in the anterior half. Some variation occurs in size of miracidia of *Z. lunata* as in other species, but most of it is due to the varying amounts of contraction and swelling which occur on natural death or fixation. Ten specimens killed by hot 0.5 per cent. silver nitrate for the silver impregnation method showed proportions most closely approaching those of the living miracidium. In these 10 specimens length varied from 184 μ to 211 μ and width varied from 53 μ to 59 μ , the average length and width being 194 μ and 55 μ respectively (Figs. 7, 8). Ten moribund specimens in hanging drops varied from 170 μ to 231 μ in length and from 68 μ to 75 μ in width, the average measurements of this group being 187 μ by 69 μ .

The entire surface except the apical papilla and the very narrow spaces between rows of epithelial cells is ciliated. The cilia (Fig. 6) are about 10 μ long except immediately behind the

apical papilla where they are about 3 or 4 μ long. These short cilia beat as do all the others. The cuticular non-ciliated cap or apical papilla is about 10 μ across and a slight constriction of the body wall occurs just behind it. The apical papilla, called by various authors a "rostrum," "oral cone," "head papilla," or a "terebratorium," is said by some to be perforated by small glandular pores. Lynch (1933) described such pores in the apical papilla of *Heronimus chelydrae*. Coe (1896) found an opening which he refers to as the mouth in the "Kopfpapille" of the miracidium of *Fasciola hepatica*. No pores were identified on this structure in *Z. lunata*, and such pores have not been reported on the papillae of other amphistome miracidia.

The external layer of the miracidium of *Z. lunata* is an epithelium consisting of 20 flattened, ciliated, epidermal cells. They are arranged in 4 tiers or rows, with 6 cells in the first (anterior) row, 8 in the second, 4 in the third and 2 in the last or posterior tier (Figs. 7, 8). These cells are well demonstrated by the silver impregnation technique used by Lynch (1933). Figure 7 is a photomicrograph of a silver impregnated miracidium taken with a 16 mm. objective to obtain sufficient depth of focus to show the entire thickness of the specimen. Figure 8 is a photomicrograph of the same miracidium as in Fig. 7 but using an 8 mm. objective focussed on the upper surface, with consequent loss of depth of focus.

The epidermal cells of the first tier covering the anterior fifth of the larval body are triangular in shape due to the tapering at the front end of the miracidium. They converge, almost meet, and seem to unite to form a ring in the base of the apical papilla. The cells of the second and third tiers are rectangular in surface view. Each of the 2 cells in the posterior tier covers one-half of the surface in the posterior fifth of the miracidium, the contiguous borders of the 2 cells lying somewhat to the left and right of the median plane. The spaces between adjoining epidermal cells and between tiers of cells in *Z. lunata* are from 0.5 μ to 1.5 μ in width as seen in silver preparations. The spaces are homogeneous in appearance, without perforations and are bordered by wavy, irregular lines. No overlapping of plates was observed. Papillae and excretory pores open laterally through spaces between epidermal cells, as will be described later.

The disposition of the epidermal plates with regard to the dorso-ventral axis of the miracidium is shown in Fig. 9, which is a dorsal view. Adjoining borders of the dorsal (and ventral) epidermal cells of the second and third rows lie in the median plane, while those of the posterior row lie in a plane about 45 degrees removed from the median plane. The borders of the 6 anterior cells do not fall in line with any of those of the second row of 8 cells, and the medial edges of the 2 dorsal epidermal cells in the anterior row lie just a little to one side of the median plane. The miracidium shown in the photomicrographs (Figs. 7, 8) lies in a position of about 45 degrees

of rotation to the right from a dorsal aspect, permitting favorable illustration of the lateral location of excretory pores and lateral papillae.

Epidermal cells have been studied in miracidia of a few other species. A review of this work was presented in tabular form by Bennett (1936). The cell formula, 6;8;4;2 was reported by Bennett (1936) for *Cotylophoron cotylophorum*, and by Krull & Price (1932) for *Diplodiscus temperatus*. The present work shows that the miracidium of *Zygocotyle lunata* also possesses the formula 6;8;4;2, indicating that this formula is probably characteristic for the family Paramphistomidae. In studies on these cells in miracidia from other families, Thomas (1883), Ameel (1934) and Lynch (1933) reported some variation between different individuals within a species. In the majority of species, however, in which the formula has been described, no variation is reported. In the present work, 25 silver impregnation preparations of miracidia of *Z. lunata* showed no variation in the formula for the epidermal plates. As pointed out by Price (1931) and Bennett (1936) these structures are probably of importance in establishing natural relationships among the trematodes.

Each epidermal cell contains a nucleus which may sometimes be seen in moribund or unstained dead miracidia, and may be best observed with the aid of intra-vitam stains. They do not show in silver impregnated preparations. In the present work they were studied from surface views of whole mounts, either unstained or stained with neutral red. The nuclei of the first tier of epidermal cells are much elongated, measure from $14\ \mu$ to $17\ \mu$ in length and about $2\ \mu$ in width, and lie very near the posterior border of the cells. Each of the 8 epidermal cells in the second tier contains an elongated but somewhat irregular-shaped nucleus near its posterior border (Fig. 9). These nuclei are $11\ \mu$ to $13\ \mu$ in length and $3\ \mu$ in width. Those of the third tier of epidermal cells show the same position, shape and length but are only about $2\ \mu$ in width. Each of the 2 posterior cells contains a centrally located nucleus about $14\ \mu$ long and $5\ \mu$ wide.

As pointed out by Bennett (1936), the nuclei of the epidermal cells have been described for only a few miracidia. With slight variations in shape, size and position, these structures are apparently similar in the miracidia of all the Paramphistomidae in which they have been investigated. In this group Sinitsin (1931) described them in the miracidia of *Paramphistomum cervi*, Krull & Price (1932) in *Diplodiscus temperatus* and Bennett (1936) in the miracidia of *Cotylophoron cotylophorum*.

Beneath the surface layer of ciliated epidermal cells is a layer of transparent subepithelial cells. As indicated by their nuclei, these cells form a continuous layer around the internal structures of the miracidium. The nuclei are distributed over all portions of the subepithelial layer, but are more numerous in the anterior half of the body (Fig. 9). In an optical section of a whole mount viewed from the dorsal side, from 13 to 15

subepithelial cell nuclei may be seen along each outer edge of the miracidium. In surface view a group of from 12 to 15 may be seen overlying the "primitive gut" and smaller groups may be identified in the middle and posterior regions of the body. A few of these nuclei appear spherical but most are slightly elongated and vary from $6\ \mu$ to $7.5\ \mu$ in length and from $4\ \mu$ to $5\ \mu$ in width. Krull & Price (1932) showed that in the miracidium of *Diplodiscus temperatus* these nuclei are arranged in 3 definite rows, and Bennett (1936) found them to be distributed in 4 principal groups in the miracidium of *Cotylophoron cotylophorum*. Bennett pointed out, however, that not all the nuclei are to be found in these groups. In *Zygocotyle lunata*, the subepithelial nuclei are distributed irregularly through the subepithelial layer, and while they are more numerous in some areas than in others no definite arrangement into groups could be observed. Actually, examination of different specimens of *Z. lunata* showed considerable variation in number and distribution of the nuclei. Bennett (1936) observed mitosis in some of the subepithelial nuclei in *C. cotylophorum* and he points out the futility of attempting to determine their number.

The "primitive gut" is a saccate or flask-shaped structure occupying a considerable portion of the anterior region in the miracidium of *Z. lunata*. Its shape is exceedingly variable both in developmental stages within the egg (Figs. 4, 5) and after hatching of the larva. It may be elongated and narrow or it may be constricted transversely, or it may shorten and become very broad. When elongated it extends past the middle of the body and when shortened it occupies only the first third of the body. No lumen in the ordinary sense of the term is present and it is completely filled with a fluid containing a coarsely granular material which surges back and forth actively due to contraction of its walls and of the body of the miracidium. Anteriorly it tapers and seems to terminate blindly just behind the apical papilla. No opening to the outside could be found and nothing was observed to be either taken in or extruded from it. Its walls show no cell boundaries in the mature miracidium. Four large, somewhat ovoid nuclei, measuring about $8\ \mu$ long by $5\ \mu$ wide, are situated near the posterior end, where they may be seen at all times since they remain attached to the wall and do not surge about with the granular contents of the sac (Figs. 5, 9).

Most helminthologists have considered the "gut" of the miracidium as a primitive or vestigial intestine but more recently the work of Reisinger (1923), Manter (1926), Price (1931), Lynch (1933), and Bennett (1936) seems to suggest that this structure is a gland rather than a gut. Bennett (1936) says, "The development of the primitive gut at some distance from the anterior end of the body, the size of the cells and their nuclei, the early development of the granular contents, the absence of a definite cell wall around each nucleus after the four-cell stage is reached, the concentration of cytoplasm around

the nuclei at the posterior end of the gut, the absence of a mouth and a lumen, and the complete disappearance of the contents immediately after penetration of the miracidium into the snail host while the nuclei may still be identified—all give evidence in favor of interpreting this structure as being a gland rather than a gut."

The writer is inclined to agree with the opinions of the above-mentioned workers that the so-called "primitive gut" is probably glandular in its function, but more intensive studies on the embryonic origin and the fate of this structure will have to be conducted before final decision can be made as to its nature. If it functions in the penetration of the larva into the snail host, an opening must develop at that time, and the granular contents may consist of secretory granules formed in a structure which might be homologous with a gut in other forms.

The excretory system of the miracidium of *Z. lunata* resembles that described for other members of the Paramphistomidae. Two large flame cells, one on each side, measuring from 13 μ to 15 μ in length of flame and from 6 μ to 7 μ in width, are located just anterior to the middle of the body (Figs. 6, 9). Each possesses a large spherical nucleus at the base of the flame. A collecting tubule passes posteriorly in loose coils from each flame cell to a level behind the excretory pores, then loops forward to encircle the flame cell and again passes back to open at the excretory pore, which is located laterally just in front of the junction of the third and fourth tiers of epidermal cells (Fig. 8). A large spherical vesicle lies just anterior to each flame cell in the miracidium during late development in the egg as well as after hatching (Figs. 5, 6). However, no morphological association could be established between them and the excretory system. No accessory excretory cells as described for the miracidia of *Heronimus chelydrae* by Lynch (1933) and no duct nucleus as reported for that of *Diplodiscus temperatus* by Krull & Price (1932) could be found in the miracidium of *Z. lunata*.

Krull & Price (1932) and Bennett (1936) reported 2 pairs of penetration gland cells in the miracidia of *D. temperatus* and *C. cotylophorum* respectively. They described these glands as 4 unicellular units extending from the base of the apical papilla backward for about one-fifth of the body length, with nuclei at their posterior extremities. From the descriptions and figures, the 4 ducts which open anteriorly are each a part of one of the 4 gland cells. No indication is given concerning their role in penetration. In the present material of *Z. lunata*, 2 nuclei with clear areas around them were found on each side at a level near the junction of the first and second rows of epidermal cells. These nuclei, slightly ovoid in shape, were about 4 μ in length. In spite of repeated observations on different miracidia at different stages of development, it was not possible to find any ducts leading anteriorly from these clear spaces around the nuclei.

The greater portion of the posterior half of the miracidium is occupied by germinal tissue, which

consists of about 40 germ cells as evidenced by their large spherical nuclei which measure from 5 μ to 8 μ in diameter. In all miracidia observed after hatching, one or more germ balls were present in addition to the germ cells. Most of the larvae contain one large germ ball measuring 25 μ across and consisting of about 16 cells with a definite membranous covering. This germ ball lies in the anterior half of the body behind the "gut" and between the flame cells. In some specimens an additional smaller germ ball could be identified. The germ balls and the larger germ cells lying in the central cavity of the miracidium appear to be completely free and not attached to any other structure.

The nervous system consists of nerve cells and fibers in association with a large ovoid mass lying dorsal to the "gut" and sending out processes laterally and posteriorly. Other processes probably extend forward but these were not observed. The dorsal nerve mass contains cells and fibers and measures about 25 μ by 30 μ . Large lateral processes could be observed in living miracidia while confined in the egg as well as after hatching. They could be traced to the body wall and were then lost. Very small cells, visible only with the aid of intra-vitam stains, lie scattered about outside of the central nerve mass.

Two papillae protrude laterally through openings between the ciliated epidermal cells at the level of the posterior border of the first tier of epidermal plates (Figs. 7, 8). They have been observed in numerous other species and have been variously called lateral papillae, anterior papillae, lateral processes and anterior ducts by different authors. They are probably sensory in function since in some forms they are described as being associated with the central nerve mass. They are about 6 μ in diameter and their position between the epidermal plates is clearly shown in silver impregnations by large round spaces. Smaller but similar spaces appear at other points of union between the first and second tiers of cells, but no structural units associated with them could be identified in *Z. lunata*. Lynch (1933) observed a number of small motionless bristles in this position in the miracidia of *Heronimus chelydrae*.

EXPERIMENTAL INFESTATION OF THE INTERMEDIATE HOST.

The intermediate host in the life cycle of *Zygocotyle lunata* is the snail *Helisoma antrosom*. Naturally infected snails of that species provided the cercarial stage from which the adults were obtained and the complete life cycle demonstrated. Laboratory-raised snails were experimentally infected with miracidia developed in eggs from feces of experimentally infected ducks and rats. *Helisoma antrosom* reproduces readily in the laboratory at all seasons of the year and was available in stock tanks at all times. All snails used in the infection experiments were laboratory-bred. Miracidia were strongly attracted to the snails, to pieces of snail or to snail

feces. To collect the rapidly-swimming miracidia from a dish, it was only necessary to place a snail in the dish and by the time one could place the dish on the stage of the microscope and focus on the snail, the miracidia would have gathered around it. They swim under and over and around the shell, occasionally attaching momentarily to the foot, edge of the mantle or to the shell, and then break away again and attach at some other point or even swim away to a different snail. If a snail is removed from the dish before penetration has occurred, the miracidia are attracted by the mucus left behind by the snail. No response to light could be observed. If no snail is present in the dish, the miracidia swim for periods up to 7 hours, settle to the bottom of the dish, and they may swim there in a narrow circle for a short time until death ensues.

Miracidia were observed with snails for varying lengths of time. In some cases miracidia disappeared under the shell within 15 minutes. Long and careful search failed to find them again and either they had penetrated or had been caught in the mucus secreted by the snail. This procedure was observed repeatedly, the time required for this apparent penetration varying from 15 minutes to 2 hours. In two cases, miracidia were seen to enter the space within the shell and attach to the base of the foot in a position perpendicular to it. Little progress, if any, toward penetration had occurred after one hour when observation was discontinued.

In all the early attempts to infect *Helisoma antrosom*, medium sized snails from 8 to 10 mm. in diameter were exposed individually in separate finger bowls to 1 to 15 miracidia. Nineteen snails were thus exposed between January and June, 1938, but none of the snails became infected. After observing the apparent penetration of the larvae into the snails, successful infections were fully expected and no explanation could be offered for the negative results. On June 29, the writer, preparing to leave for Woods Hole, dumped about 40 eggs which were due to hatch 2 days later, into a battery jar containing some very young laboratory-raised snails. Another batch of 70 eggs of *Z. lunata* due to hatch July 8 was placed in a 2-gallon aquarium jar containing laboratory-raised snails of various sizes. Returning to the laboratory on August 17, the writer found encysted metacercariae on the glass in both jars. Isolation of the 42 snails showed 9 infestations, all but one of which were in snails 7 mm. or less in size. The single larger infected snail was 13 mm. in diameter.

On August 27, 20 eggs of *Z. lunata* with miracidia ready to hatch were put into a finger bowl with 3 very young snails, each being about 2 mm. in diameter, and 35 days later 2 of the 3 snails began giving off cercariae. Young snails from 2 mm. to 6 mm. in size were used in all later experimental infections. Mass infections using large numbers of miracidia in small aquarium jars containing from 20 to 75 snails were much more successful than when a single individual was exposed to a few miracidia in a separate

dish. In such mass infections, from 10 per cent. to 55 per cent. of the snails became infected. Not less than 80 successful experimental infestations of *Helisoma antrosom* were obtained in which mature cercariae were produced. Many other experimentally infected snails were killed for dissection or sectioning during the early stages of the infestation. The miracidium metamorphoses in the snail into a sporocyst which in turn produces rediae. The redial generation gives rise to cercariae which emerge from the snail from 32 to 49 days after penetration of the miracidium.

The snail host may carry an infestation with *Z. lunata* for long periods. The 4 naturally infected snails from which the life history studies began were collected in September and October, 1937, at which time they were giving off cercariae in numbers up to 100 per day. Of these, one died on December 29, 1937, 2 others died in April, 1938, and the 4th, which was recorded as a light infestation the previous September, lived until June 25, 1938. During this period they were kept isolated in finger bowls and fed lettuce leaves, and the water was changed about once a week. Many thousands of cercariae were produced. Some of the experimental infections persisted equally long. From a group of 12 snails which began giving off cercariae on December 18, 1938, seven were still living in the laboratory and shedding cercariae after 9 months. From a size of not more than 5 mm. when infected they had grown to an average size of 15 mm. in diameter of shell. No snails were exposed to miracidia a second time after they were once infested with *Z. lunata*. None was observed to have lost the infestation and those which were crushed or died naturally after giving off cercariae for 9 months still contained large numbers of immature and mature rediae and cercariae. The larvae infest most heavily the liver and gonads of the snail host but rediae and immature cercariae are found in considerable numbers in the lymph spaces and practically everywhere in the snail except in the lumen of the intestine. None of the snails produced any eggs after becoming infected. As seen in sectioned snails, the gonads are reduced to a few shreds of tissue or cannot be identified at all.

SPOROXYST.

The sporocyst of *Z. lunata* was observed only in the mature condition. Attempts to find early sporocysts by dissection of snails within a few days after exposure to miracidia were unsuccessful. Mature sporocysts were found in snails sectioned from 22 to 28 days after penetration of the miracidium. At this stage many rediae and immature cercariae are already free in the tissues of the snail. Usually no sporocysts can be found in an infected snail which has begun to shed cercariae, but one snail dissected 47 days after infestation, yielded a sporocyst measuring 297 μ in length and 195 μ in width which contained a single well-developed redia and nothing else. On manipulation of the coverslip the wall was ruptured and the young redia emerged. All other

snails dissected later than 28 days after infestation failed to yield sporocysts. No sporocysts of *Z. lunata* were found in the naturally infected snails studied.

The mature sporocyst varies in shape from ovoid to elongate and is broader anteriorly than at the posterior end. It is a simple saccate structure with a body wall consisting of a cuticle, a membranous sheet and muscle fibers. Within the central cavity are germ balls and young rediae in various stages of development. The excretory system is that which is carried over from the miracidium and consists of a pair of flame cells with collecting ducts which open laterally a short distance behind the middle region of the body. A terminal bladder was observed on each side.

A mature sporocyst found in sections of a snail killed 28 days after penetration of the miracidium contained 2 germ balls at the posterior end and 5 young rediae which occupied the central cavity. A reconstruction of this specimen is shown in Fig. 10. Each of the contained rediae shows a well-developed pharynx and an intestine which occupies most of the space within the young larva and extends nearly to its posterior border. The pharynx varied in diameter from 23 μ in the 2 individuals in the posterior region to 27 μ in the young redia near the anterior end. Figure 14 is a photomicrograph of one of the sections of this sporocyst and shows parts of 4 of the 5 rediae. The pharynges shown are those of the two posteriorly placed rediae.

REDIA.

The redial generation of *Zygocotyle lunata* was described by Willey (1936) in a paper on *Cercaria poconensis*. Since *Cercaria poconensis* Willey, 1930, is the larva of *Z. lunata*, the mature redia need not be again described here. However, since only naturally infected snails were available for the previous study, no information was obtained on the early stages of infestation. With an abundance of material from experimentally infected snails it has been possible in the present investigation to make more complete observations which reveal the presence of daughter rediae.

In the earlier description (Willey, 1936) of the stages found in the snail, it was stated that, "All the snails examined showed very many rediae of all sizes, but no sporocysts or mother rediae were found." Many very small rediae as well as larger ones are always to be found in crushed infected snails, even in those killed 9 months or longer after experimental or natural infestation. This fact indicated strongly the existence of two generations of rediae, since the sporocyst disappears early in the course of the infestation. Accordingly, in the present study, experimentally infected snails were dissected or sectioned at different periods following penetration of the miracidium of *Z. lunata*. Most of the observations were made on living material from crushed snails, but sections of infected snails also show all the more important stages.

In some of the snails crushed during early stages of the experimental infestations, mother rediae were found which contained only a single daughter redia and a few undeveloped germ balls near the posterior end. A specimen of this type shown in Fig. 11 was 330 μ long and its pharynx measured 33.4 μ in diameter. The daughter redia was 198 μ in length and its pharynx also measured 33.4 μ in diameter. The young redia showed considerable movement within the parent and its intestine extended back more than three-fourths of the length of the body. In this early stage of infestation no cercariae were as yet to be found free in the tissues of the snail, but rediae were also present which contained only developing cercariae (Fig. 15). In a group of snails crushed 20 days after experimental infestation, numerous rediae were present which contained a single daughter redia and 3 to 6 germ balls which were not as yet differentiated. In no case could more than a single daughter redia be identified within a parent redia.

Infected snails, killed 25 days or later after penetration of the miracidium, contained mother rediae with one daughter redia and numerous immature cercariae. Few such mother rediae were present in any one snail, but all snails examined between 25 and 47 days following infestation contained this stage in addition to many rediae in which only cercariae could be observed. The identification of the different larval stages within the same mother redia was unmistakable. The single daughter redia seen in Fig. 13 showed much movement, squirming and turning around actively. The several cercariae present were larger and showed no movement. The well-defined pharynx in the daughter redia measured about 30 μ in diameter, while the oral sucker of a developing cercaria is much larger, when it first becomes definable, than the pharynx of a large mature redia. Further, in some cases the eye-spots of the cercariae had begun to develop. The cones of cilia in the flame cells of daughter rediae are from 11 to 13 μ in length, whereas those of cercariae of this species are only from 5 to 7 μ long.

Mother rediae containing both a daughter redia and cercariae were found in laboratory-infected snails studied during the period from August to March, but it seems probable that rediae are produced singly by mother rediae throughout the course of the infection. This is indicated by the fact that infected snails at all stages of infestation always contain great numbers of mature and immature rediae of various sizes free in the tissues. They must be produced more or less continuously in the snail host and emerge from the parental generation at a relatively early stage. All daughter rediae observed were located in the anterior region of the mother rediae and they are always produced singly. Rediae containing only a daughter redia and no cercariae (Fig. 11) are small and are found only in the early stages of the infestation. Rediae containing both a single daughter redia and cercariae were all older and larger individuals

measuring from .7 mm. to .9 mm. in length. The redia shown in Fig. 13 was .792 mm. long and contained a daughter redia measuring .335 mm. by .066 mm., while that in Fig. 12 was .860 mm. in length and contained a much younger daughter redia which measured .172 mm. in length and .063 mm. in width. These facts suggest the probability that each redia produces one daughter redia and proceeds from that time on to produce cercariae only. This would explain the presence of rediae of all sizes during all stages of the long-term infestation in this species.

The rediae move sluggishly when freed from the snail, and in a watch glass usually remain in one place with only slight changes in body shape due to muscular contraction. No locomotor appendages are present at any stage. Twelve flame cells are present in the mature redia of *Z. lunata* while only 6 appear in younger individuals. Most amphistome rediae described show a total of only 6 flame cells in the excretory system of the mature redia. Looss (1892) mentions 4 flame cells on one side in the redia of *Diplodiscus subclavatus* and Krull & Price (1932) figure a total of 7 in that of *Diplodiscus temperatus*. Looss (1896) described 5 pairs of flame cells in the mature redia of *Paramphistomum cervi*.

A daughter generation of rediae has been described for several species of amphistomes. Looss (1896) reported more than a single generation of rediae in *Gastrodiscus aegyptiacus* and in *Paramphistomum cervi*. In life history studies on *P. cervi*, neither Takahashi (1928) nor Szidat (1936) were able to find any evidence for a second generation of rediae. Beaver (1929) described 2 generations of rediae in *Allassostoma parvum*. Le Roux (1930) indicated that mother rediae occurred in the life cycle of *Cotylophoron cotylophorum* and Bennett (1936) found one specimen of a mother redia in that species. Krull & Price (1932) reported only one redial generation for *Diplodiscus temperatus*, but Herber (1938) demonstrated both mother and daughter rediae in that species. The development of rediae and cercariae within the same mother redia is known for only one other species of amphistome, and the present work constitutes the second report of this condition in amphistomes. Looss (1896) described a redial generation of this type in *Gastrodiscus aegyptiacus*. He figures a redia containing 3 daughter rediae and 3 cercariae and states that rediae containing only cercariae are rarely encountered in that species.

Some authors have postulated that in certain forms a definite number of rediae and cercariae are produced. In the absence of experiments with known numbers of miracidia infecting the snails, no definite conclusions can be reached in this regard in any species of trematodes. In *Zygocotyle*, the finding of only small numbers of mother rediae containing single daughter rediae and cercariae together indicates that the production of rediae is a continuous process and is not limited to a definite number. Variations may occur in the redial generations in the snail under natural conditions accompanying seasonal

changes. Experimentally infected snails kept under laboratory conditions do not always afford sufficient information on which to base conclusions concerning the prevalence and numbers of the various larval stages. The course of events probably varies with changing conditions. Much work still remains to be done on these problems of development.

CERCARIA.

The cercaria of *Zygocotyle lunata* was named *Cercaria poconensis* in an abstract by Willey (1930), and in 1936 he described the redial and cercarial generations together with a report of infestation experiments with the metacercarial stage. The cercaria need not be redescribed here and only additional information not available from the earlier studies will be presented. The material from which *C. poconensis* was described and that from which the life history of *Z. lunata* is demonstrated in the present study are unmistakably identical. The size and the shape and distribution of the body organs in the two groups of specimens agree perfectly. The size measurements vary somewhat with different degrees of flattening. For example, the oral sucker in fixed and unflattened cercariae shows an average measurement of .064 mm. in diameter, while in living specimens, flattened under medium pressure, it may be as large as .106 mm. across. The oral sucker and oral evaginations together measure .165 mm. in length in fixed, unflattened individuals.

Näsmark (1937), in a revision of the Paramphistomidae, has attempted to show that the sucker at the anterior end in amphistomes is a pharynx rather than an oral sucker. On the basis of histological studies, he believes that this structure is homologous with the pharynx of the monogenetic trematodes and the rhabdocoel turbellarians, and states that contrary to the opinion of Looss (1902) and others it should be designated a pharynx. However, due to the incomplete nature of Näsmark's evidence, the conclusions are not accepted by the present author and the sucker is here referred to as an oral sucker. Fiscoeder (1903) referred to the anterior sucker of *Z. lunata* as a pharynx, causing some misinterpretation in the literature, but all the more recent authors have preferred to call it an oral sucker. Until final conclusive evidence is forthcoming, the terminology currently used seems more desirable.

The posterior overhanging lip of the acetabulum with its 2 lateral conelike projections (Figs. 21, 22), which are so characteristic of the genus *Zygocotyle* in the adult stage, were not observed in the earlier studies on the cercarial stage. But after it became known that this cercaria was the larval stage of *Zygocotyle*, the lip and conical projections were observed from the ventral surface of cercariae when under only slight pressure. This modification of the acetabulum is present on the cercaria in an immature condition. Figure 16 is a photomicrograph of a living cercaria under medium pressure and shows the

relationships of the various organ systems. The characteristic branching of the main excretory ducts is clearly outlined by the presence of excretory concretions. Drawings from both living and fixed material of redial and cercarial generations appear in the earlier description (Willey, 1936).

The cercaria leaves the redia while still in a very immature condition. The intestine, oral sucker, acetabulum, eye-spots, tail rudiment and the excretory system, already laid down while the cercaria is in the redia, continue their development after emergence. Some variation occurs in the size and degree of differentiation of the cercariae at the time of emergence. Young cercariae are frequently observed free in the tissues of the snail which have not developed as far as other cercariae which are still within nearby rediae.

In experimental infestations, young cercariae were first found free in the tissues of snails crushed 16 days after exposure to miracidia. In other snails, crushed 20 days after exposure to miracidia, none had as yet emerged from the rediae. The rate of development is known to vary with temperature conditions. The time required for the complete development of the cercaria, from penetration of the miracidium until shedding of the first mature cercaria from the snail, varied in the laboratory from 32 days during the warmer months to 49 days during the winter.

After emergence, cercariae swim about vigorously in the water at the side of the container toward the light for 30 minutes to 2 hours. They respond very rapidly to changed lighting conditions and will follow a beam of light moved about from one side of the dish to the other. Encystment occurs on the side of the dish toward the light, on the shell of the snail, or occasionally on vegetation. If handled or otherwise irritated they encyst almost immediately, often attaching and encysting within a dropper when being transferred to a slide for examination. If placed on a slide in a small amount of water, a coverglass must be added immediately to prevent encystment. The shell of a snail producing cercariae is usually crowded with encysted metacercariae. Cercariae emerge in greatest numbers between 10:00 A. M. and 2:00 P. M. and usually only on bright days. On dull, rainy days very few or none escape, while on bright, sunny days as many as 100 may emerge from a single infected snail at the peak of the infestation. Cercariae may be produced from an infected snail for 9 months and longer, but the number of cercariae escaping each day decreases as the snail remains longer in the laboratory. Little difference could be observed between the numbers of cercariae produced in naturally and experimentally infected snails.

METACERCARIA.

The cercaria encysts and passes into the metacercarial stage in which it awaits ingestion by the final host. The process of encystment is very

rapid. The cercaria attaches itself by means of its suckers, the tail vibrates from side to side somewhat more slowly than in swimming, and the body appears to undergo rapid squirming movements. Cystogenous material then oozes out rapidly over the surface of the body from the elliptical cystogenous granules which occupy most of the dorsal half of the cercaria. The cyst wall forms rapidly and the tail is left attached to the outside of the cyst, where it lashes violently for an hour or more and then drops off, sinks to the bottom and may continue lashing about for several hours. The body of the cercaria twists and turns about during the process as though molding the inner wall of the cyst. Finally the cyst wall hardens, the metacercaria coils about in the cyst and after several hours becomes relatively motionless with suckers apposed, periodically undergoing slight twitchings and contractions in various regions of the body.

The cysts are large dome-shaped hemispheres with thick resistant walls which are brown to black in color when seen with the naked eye. The base of the cyst flares out slightly from the margin of the cyst proper (Fig. 18). When formed on glass they are flat on the bottom and the greatest diameter shows an average measurement for 10 metacercariae of .368 mm. The diameter at the base of the dome varies in 10 individual cysts from .277 mm. to .343 mm., the average being .289 mm. Figure 19 is a photomicrograph of a 10-day old metacercaria which has been dissected from its cyst. When removed thus in water or salt solution, they contract and undergo little or no movement. Much black pigment is present in the body wall and this tends to obscure the internal structures, which show no advance in development over the condition found in the cercaria. The black pigment of the eye-spots and body persists throughout metacercarial life and scattered granules of eye-spot pigment are still present after 3 weeks of development in the final host (Figs. 21-23).

Infestation Experiments with Metacercariae. Early attempts to infest the final host with the metacercaria of *Z. lunata* were conducted, using cold-blooded hosts. As outlined by the writer in an earlier paper (1936), encysted metacercariae were fed to tadpoles but all the experiments were negative. In 1937, following unsuccessful attempts to infest turtles with the larvae, some of the metacercariae were dissected from their cysts and placed in cold Ringer's fluid at 20° C. All were dead after 3 hours. Artificial digestion of some of the metacercariae from their cysts with pepsin and pancreatin solutions at 37° C. indicated that the final host was a warm-blooded animal. Under this treatment the cyst walls became soft and movement of the metacercaria was observed after 4 hours. After 10 hours and up to 20 hours of artificial digestion, young worms were still alive in the cysts while others showed much activity on being released from the cyst.

Consequently on October 8, 1937, 2 young laboratory-raised rats were each fed about 65

metacercariae obtained from the naturally infected snails as described earlier in the paper. Five days later one of the rats was killed and yielded 59 young worms in the cecum with none above or below this level in the intestine. Development had proceeded far enough to permit identification of the worms as *Zygocotyle*. The small cone-like projections on the posterior edge of the acetabulum are well developed at this stage (Fig. 20). The worms, still immature, show average measurements for 10 of them of .940 mm. in length and .460 mm. in width. The common natural hosts of *Zygocotyle* are various species of ducks. Thirteen young ducks were subsequently fed varying numbers of cysts and all became infected. Similarly, in the course of the investigation, more than 60 rats and one ram were experimentally infested. Attempts to infect pigeons and rabbits gave negative results.

In order to determine the time required for the young worms to mature in the final host, fecal examinations were conducted almost daily on some of the experimental hosts. Two ducks, (nos. 1 and 3) fed metacercariae on October 14, 1937, began giving off eggs of *Zygocotyle* in fecal material on November 24, or on the 41st day of infestation. Duck number 3 was killed 5 days later and contained 7 mature specimens of *Zygocotyle lunata*, 5 in one cecum and 2 in the other. Similarly 4 rats (nos. 3, 4, 5 and 6) were fed from 30 to 40 encysted metacercariae each on October 14, 1937. On November 24, when the 2 ducks described above showed eggs in the feces, the rats were still negative. One rat, number 5, killed on November 28, the 45th day, contained 23 *Zygocotyle*, several of which showed a few eggs in the uterus near the ovary, but none was fully mature as yet. Eggs of *Z. lunata* from this series of rats first appeared in the feces of rat number 6 on the 46th day after infestation. This rat was killed on December 4, the 51st day after the experimental feeding, and contained 8 fully mature *Zygocotyle lunata* in the cecum. The more rapid development in the duck may possibly be due to the higher body temperature maintained by that host. This difference was confirmed in other series of infected rats and ducks, the data for which will be described later.

Thus, beginning with cercariae from naturally infected snails, all stages in the development of the adults of *Zygocotyle lunata* were obtained in rats and ducks. As described in the earlier sections of the present paper, eggs from feces of the experimental hosts were embryonated to produce miracidia which were experimentally introduced into laboratory-raised snails. In the snail, *Helisoma antrosom*, the sporocyst and the redial and cercarial stages were obtained and the complete cycle was carried out several times in the laboratory.

Experiments on Infectivity of Metacercariae. After experiment the metacercaria remains quiescent and awaits ingestion by the final host. No development occurs within the cyst. Metacercariae dissected out or freed from their cysts by artificial digestion after one day of encystment

are in no way distinguishable from those similarly freed after 20 or 30 days. This observation was confirmed by feeding experiments with rats. Cysts in a few drops of water were placed on small pieces of bread and given to the rats after withholding all food for 24 hours. In an experiment conducted on December 30, 1937, rat 22 was fed 100 metacercariae which were 14 days old and rat 25 was fed 100 metacercariae which were 85 days old. Both rats were killed 15 hours after ingesting the larvae and each rat yielded more than 30 excysted worms in the cecum. Some larvae were still within their cysts and none could be found anywhere in the digestive tract other than in the cecum. No significant difference could be detected between the two groups of young worms. All were equally active and the number of worms found was approximately the same in the two hosts. In an experiment designed to detect any changes which might occur immediately after encystment of the metacercaria, rat 12 was fed 50 newly encysted larvae, some with the cercarial tail still attached and the cyst wall still soft, and rat 11 was fed 70 metacercariae which were 47 days old. Both rats were killed 3 days later and yielded young worms in the ceca which were practically indistinguishable morphologically in the two hosts. Thirty-five worms were collected from rat 12 which received 50 newly formed cysts and 60 worms were obtained from rat 11 which received 70 cysts 47 days old. A few cysts are probably destroyed by the rat in the chewing of the bread. In a third experiment, one rat (no. 23) was fed 15 metacercariae which were 2 days old and 15 which were 32 days old. This rat was killed 6 days later and the 20 young worms collected from the cecum showed no significant differences in size or degree of differentiation. The rate of development of *Zygocotyle lunata* to sexual maturity is not correlated with the age of the metacercaria at the time of its ingestion. These experiments show conclusively that no development occurs in the cyst of *Z. lunata* and also that the encysted metacercariae are infective immediately after encystment.

Longevity. In one of the foregoing experiments, metacercariae, encysted for 85 days, were viable when fed to rat 25. In a series of longevity experiments, it was determined that the metacercaria will live much longer than that. Encysted metacercariae were kept at room temperature in the laboratory in covered finger bowls attached to the glass wall where first deposited, and the water was not changed except to add water occasionally to make up for evaporation. Metacercariae not older than 3 months were viable and when fed to rats produced infestations with *Z. lunata*. Encysted larvae older than 4 months gave variable results (Table 2). The oldest metacercariae which successfully produced an infection in rats had been in the laboratory for 138 days. In this experiment rats 48 and 49 were each fed 50 metacercariae from cercariae emerged from snail number 2 on January 30, 1938. Movements of the larvae within

TABLE 2.

Longevity of encysted metacercariae of *Zygocotyle lunata*.

Host and date of feeding metacercariae	Age of metacercariae in days	Number of metacercariae ingested	Elapsed time before killing host (Days)	Number of worms recovered	Remarks
Rat 34 June 2, 1938	86	10	11	3	
Rat 35 June 2, 1938	86	10	11	8	
Rat 30 Feb. 3, 1938	121	100	46	0	Movement observed in cyst before feeding to rat
Rat 29 Feb. 3, 1938	131	100	46	0	Movement observed in cyst before feeding to rat
Rat 46 June 9, 1938	130	50	9	23	Movement observed in cyst before feeding to rat
Rat 47 June 9, 1938	130	50	9	28	Movement observed in cyst before feeding to rat
Rat 48 June 17, 1938	138	50	169	1	Eggs in feces after 74th day
Rat 49 June 17, 1938	138	50	169	2	Eggs in feces after 74th day
Rat 63 Feb. 10, 1940	152	50	14	0	Cysts shrunken
Rat 44 June 4, 1938	166	150	9	0	Movement in 10% Cysts not examined
Rat 45 June 4, 1938	166	150	9	0	Cysts not examined
Rats 64, 65, 66, 67 Feb. 29, 1940	171	25 each	5-10	0	Cysts shrunken No movement observed

the cyst were observed before feeding. Seventy-four days later many eggs of *Z. lunata* were collected from feces of both rats and when these 2 rats were killed after 6 months of infestation, large, adult specimens of *Z. lunata* were recovered. In a similar experiment with rats 46 and 47 (Table 2), metacercariae 130 days old were fed and when the rats were killed 9 days later, 23 young worms were recovered from the cecum of rat 46 and 28 from rat 47. As indicated in Table 2, cysts 152, 166 and 171 days old respectively were fed to rats but no infestations resulted.

Some variation in longevity occurs. In the experiment involving rats 29 and 30, no infection was obtained from metacercariae aged 131 and 121 days respectively, although movement was detected within the cyst. Minor variations in other factors would readily account for such slight variations in longevity and infectivity. That these are not due to individual differences in the host reaction is indicated by the fact that in most of the experiments dealing with longevity of metacercariae, 2 host animals were fed similar numbers of larvae produced from the same snail host on the same dates, and in each case the results were always the same in the 2 hosts concerned.

No evidence is available as to what constitutes optimum conditions for long survival of encysted metacercariae. Bennett (1936) reports that under optimum conditions the metacercaria of *Cotylphoron cotylphorum* probably lives for several months. In his experiments, he presumably kept them at room temperature and after 3 months (June 5 to September 5) 33 per

cent. were still alive. At this point observations were discontinued. Krull (1934) kept metacercariae of the same species alive under the same conditions for as long as 5 months from July 2 until December 2. Both of these workers used the criterion of movement of the metacercaria to determine its life span. As indicated by the data on rats 29, 30 and 63 (Table 2), movement in the cyst shows the metacercaria of *Z. lunata* to be alive as long as 5 months, but such larvae, when fed to the final host, were in these three attempts unable to survive conditions within the final host. It seems probable that motility is not a valid criterion of infectivity.

Experimental Studies on Viability of Metacercariae. Experimental feedings conducted with rats show that at least 85 per cent. of the metacercariae of *Z. lunata* excyst and survive for a time in the final host. The percentage of viable metacercariae is probably higher since some of the cysts may be destroyed in the chewing process by the rat host. The number of metacercariae which have excysted and are recoverable as young worms is seen to be very high if the host is killed within the first few days after ingestion of the cysts, because, as will be shown later, the host may begin to lose some of the worms as early as the second or third day. Table 3 shows the number and percentage of worms obtained in 10 experiments in which the hosts were killed within the first 11 days. The high percentage of viability of metacercariae is shown in feeding experiments with ducks as well as rats. For example, duck 3a, fed 150 encysted larvae and killed 11 days later, yielded 144 young worms in the ceca.

TABLE 3.

Viability of encysted metacercariae of *Zygocotyle lunata*.

Host	Metacercariae ingested by host		Days elapsed before killing host	Number of worms recovered	Percentage of worms recovered
	Number	Age (Days)			
Rat 7	90	12-18	2	85	94.4
Rat 11	70	47	3	60	85.7
Rat 12	50	0-2 hrs.	3	35	70
Rat 1	65	8	5	59	90.7
Rat 23	30	2-32	6	20	66.6
Rat 6a	60	1-3	7	55	91.6
Rat 6b	80	30	7	74	92.5
Rat 3	30	11-14	11	25	83.3
Rat 36	75	10-30	11	60	80
Duck 3a	150	9-16	11	144	96

Average percentage of viability over 11 days 85%

In order to determine the effect of low temperature on metacercariae, a finger bowl containing several hundred larvae encysted on the glass was placed outside on a window sill on March 2, 1938, for 11 days, during which time the temperature varied from 8° Fahrenheit to 45° F. During the night of March 3 the temperature dropped to 8° F. and the water in the dish was frozen solid for at least 15 hours. The dish was then brought into the laboratory, and as the ice melted the cysts came loose from the wall of the dish and fell to the bottom. They were examined several hours after all the ice had melted and were found to contain living metacercariae actively moving within the cyst. About 120 of these metacercariae were fed to rat 31 which was killed 16 days later. Eighty 16-day old worms were recovered from the ceum. The rest of the cysts had been again placed outside, exposed to freezing temperatures almost every night. After 10 days of such exposure, some were fed to rat 33, which, when killed 11 days later, showed only 6 worms in the ceum. The experiments demonstrate that encysted metacercariae of *Z. lunata* are able to withstand complete freezing of the water around them for at least 15 hours and that some are still viable after 10 days of alternate freezing and thawing. This phase of the problem was not carried further because consistently low temperatures were no longer available.

The metacercariae of *Z. lunata* are unable to withstand prolonged drying. A finger bowl containing several hundred viable larvae (30 days old) encysted on the glass was left uncovered without water in the laboratory on March 2, 1938. Twenty-four hours later a few cysts were scraped off and examined and the larvae still looked normal and showed occasional movements. After 48 hours, more were removed and although the metacercariae looked normal no movement was observed. Water was again placed in the dish and metacercariae examined on the next day still showed no movement. One hundred of the cysts were fed to rat 32 which when killed

16 days later contained no worms. Apparently the encysted metacercariae do not survive for long when exposed to the air.

DEVELOPMENT IN THE FINAL HOST.

Observations recorded in the literature on development of amphistomes in the final host are very fragmentary, consisting of only a few scattered and incomplete reports. In the present study, an attempt is made to investigate this stage in the life history rather completely since the experimental hosts, rats and ducks, are favorable for such studies. These hosts show practically a 100 per cent. susceptibility to infection with metacercariae of *Zygocotyle lunata*. All the ducks (13) fed became infected on the first experimental feeding, as did all the rats (more than 60) except those few which were fed metacercariae shown experimentally to be not viable. Both rats and ducks were given the encysted larvae in a few drops of water which was soaked up in small pellets of bread. The pellets were pushed down the throats of the ducks, and the rats after having food withheld for 24 hours ate the bread readily. In some cases the piece of bread was moistened with milk to hasten its ingestion by the rats. Apparently few of the cysts were destroyed in the chewing process, for as described previously, at least 85 per cent. of the metacercariae developed in the experimentally-fed rats (Table 3).

The single sheep (an adult ram) which became infected with *Z. lunata* did not take the infestation on the first feeding. On October 21, 1937, the ram was given 109 viable metacercariae which were mixed with a handful of moistened oats in a porcelain evaporating dish. The cysts stuck to the moist oats and were undoubtedly ingested. Ten fecal examinations were made between November 26, 1937, and March 1, 1938. All were negative. The cysts may have been destroyed in the chewing process. On March 3, 400 metacercariae were placed in a small amount of water in an evaporating dish. Since the ram had been deprived of water for 48 hours he drank the water and swallowed most of the cysts. He was similarly given 600 metacercariae two days later. In three examinations conducted on May 19, 21 and 26, eggs of *Z. lunata* appeared in considerable numbers in the feces. Since the ram was being used for other experiments, no opportunity was afforded to follow the course of the infestation or to obtain the worms. Therefore, this host record rests entirely on the presence of eggs of *Z. lunata* in the feces. However, since thousands of eggs of this species had been collected and studied from the rats and ducks during this period, little, if any, possibility of error in identification of the eggs exists. The only other flatworm to which the ram was exposed was the tapeworm, *Moniezia*. It also carried nematode worms, as evidenced by the presence of nematode eggs in the feces from time to time.

Two pigeons were each fed 50 viable metacercariae on October 23, 1937. Fecal examinations were consistently negative, and, when on

January 29, 1938, both were killed, no worms were found. Similarly a rabbit fed metacercariae showed no eggs of *Z. lunata* in the feces and no worms were found when it was killed 58 days later. No attempts were made to infest other pigeons and rabbits.

In nature, the final host becomes infected with *Z. lunata* by ingesting the encysted larva from pond weeds, or ducks may eat small snails, the shells of which bear encysted metacercariae. In the laboratory, the snails, both naturally and experimentally infested, and other snails which may be in the same dish, become encrusted with many cysts. The 3 cysts shown in Fig. 18 are held together by an underlying piece of thin snail shell on which they were deposited. Similarly some of the uninfected *Helisoma antrosom* collected along with those naturally infected carry a few cysts on their shells.

Excystment probably does not occur in the upper intestine. Rats 22 and 25 were each fed 100 viable encysted larvae on December 30, 1937, and were killed fifteen hours later. In both cases examination of the small intestine yielded no young worms or encysted larvae in that region. In the cecum many newly excysted worms, most of which were not yet attached to the wall of the cecum, were found. Only 30 were collected from each of the hosts, although many more were present. The ceca of both rats contained numerous metacercariae which were still encysted. In rat 22, 25 were collected and these when dissected out from within the softened cyst wall were alive and active. From this observation and the fact that at least 85 per cent. of the metacercariae regularly excyst and develop for at least several days in the final host (Table 3), it seems apparent that excystment usually occurs in the cecum in rats. No evidence on this point is available for ducks.

Zygocotyle lunata occurs normally as a parasite in the cecum of certain water birds, and has been reported from the cecum in the ruminants, *Cervus dichotomus*, by Diesing (1836), and *Bos taurus*, by Price (1928). In the present studies, specimens collected from experimentally infected ducks were always found in the ceca except for one worm in the bursa of a duck killed 14 days after infestation. No specimens were present in the intestine of any of the ducks examined. In the experimental rats the worms were usually found only in the cecum, but in each of 2 cases, 2 worms were found in the large intestine. In agreement with the opinion of Gower (1938), it is believed that the intestine in birds is an abnormal habitat for *Zygocotyle*, and that the parasites merely move out of the cecum after the death of the host. Specimens located in the large intestine of the rat are on the way out of the host in the normal reduction of numbers that occurs. As will be described later in the present paper, the parasites are still intact when extruded with the feces. The worms were usually found within one inch of the distal ends of the ceca in freshly killed ducks.

TABLE 4.
Experimental infestation of ducks with *Zygocotyle lunata*.

Host No. and date of first feeding	Number of metacercariae fed	Sexually mature, first eggs in feces, (days)	Days elapsed before killing host	Number of worms recovered
1, 10/14/37	50	41	744 10/28/39	0 (Eggs in feces on 10/26/39)
2, 10/14/37	50	—	14	4
3, 10/14/37	50	41	47	7
4, 10/30/37	100	—	14	6
10/14/37	1?	—	31	1
5, 12/13/37	5	—	7	1
1a, 11/20/37	100	44	359	2
2a, 11/20/37	100	44	56	17
3a, 11/20/37	150	—	11	144
4a, 11/20/37	60	—	286	10
5a, 11/20/37	60	—	507	5
6a, 11/20/37	60	—	711	3
12, 7/18/39	100	42	—	—
13, 7/18/39	100	42	—	—

Some variation exists in the time required for *Z. lunata* to develop to sexual maturity. In ducks, they develop more rapidly than in rats. As indicated by the earliest appearance of eggs of *Z. lunata* in the feces, ducks 1 and 3 contained sexually mature worms at 41 days, ducks 12 and 13 at 42 days, and ducks 1a and 2a on the 44th day after experimental infestation (Table 4). A greater amount of variation was observed in the time elapsed before appearance of eggs in the feces of the rat hosts. As shown for 6 of the rats in Table 5, the required time varied from 46 to 61 days. The rate of development is influenced to some extent by the number of worms present. Rat 6, in which the worms developed to maturity most rapidly, harbored only 8 large, mature specimens when killed five days after the first appearance of eggs in the feces. On the other hand, rats 8, 10 and 15, in which from 58 to 61 days were required before eggs appeared in the feces, harbored 23, 30 and 34 specimens respectively, when killed a few days later (Table 5). Rats 8 and 15 contained some specimens which were still not quite mature and contained no eggs in the uterus. The variation is probably related to the large number of worms present, since, as will be shown later, the rate of development is influenced by crowding. When only a few specimens are present, they tend to be all of the same size and at the same stage of development, whereas in hosts harboring many worms, the size and rate of development vary considerably. For example, rat 15, killed 70 days after a single feeding of metacercariae, contained 34 specimens of *Z. lunata* which after fixation varied in length from 3.4 mm. to 5.4 mm. and in width from 1.5 mm. to 1.9 mm., and some were not yet sexually mature although as stated above, eggs were present in the feces ten days earlier, indicating that some were mature at that time.

The faster rate of development of *Z. lunata* to

TABLE 5.

Reduction in number of worms with increase in age of infestation in rats.

Rat No.	Number	Metacercariae ingested by host		Mature, first eggs in feces (days)	Days elapsed before killing host	Number of worms recovered	Percentage of worms recovered
		Age (days)	Number				
26	150	20-30			22	120	80
4	30	10-14			23	25	83.3
5	30	10-14			45	23	76
6	30	10-14	46	51	8	8	26
8	70	12-18	58	59	23	23	32
10	70	12-18	61	61	30	30	42
15	50	20-40	60	70	34	34	68
13	50	20-40		92	28	28	56
14	50	20-40		92	2	2	4
48	50	138		169	1	1	2
49	50	138		169	2	2	4
37	75	10-30		184	2	2	2.6
38	75	10-30		184	0	0	0
39	75	10-30		184	3	3	4
40	75	10-30		184	3	3	4
41	75	10-30		184	0	0	0
42	75	10-30		184	3	3	4
43	75	10-30		184	3	3	4
16	50	20-40		193	0	0	0
17	50	20-40		193	0	0	0
18	50	20-40		193	5	5	10
19	50	20-40		193	0	0	0
20	50	20-40		193	0	0	0
21	50	20-40		193	3	3	6
60	50	?		226	4	4	8
52	50	?		238	2	2	4
58	50	20-30	53	343	2	2	4
50	50	?		424	1	1	2
28	100	20-30		711	1	1	1
62	50	20-30	49				

sexual maturity in ducks is related not only to the higher body temperature of the bird host, but also to the fact that the ducks harbor fewer parasites of this species than do the rats. In infected rats, killed any time up to the 11th day after infestation, most of the worms are still present, but after that a gradual loss of worms occurs (Tables 3, 5). In ducks the results are not uniform with regard to the percentage of worms remaining at different ages of the infestation (Table 4), but this is probably due to the fact that variable numbers of metacercariae reach the ceca of the bird, many being eliminated because of this failure to reach the normal site for development. From the data on number and size of worms present at the time when they reach maturity, specimens of *Z. lunata* are fewer and larger, and they mature more rapidly in the duck than in the rat.

Although large numbers of worms may be present early in an infestation (Table 3), relatively few persist for long after sexual maturity is attained. In 20 of the rats listed in Table 5 the infestation was older than 100 days when the host was killed. Not more than 5 were found in any one rat and the usual number was 2 or 3. In 6 of these cases, rats killed 184 or 193 days after infestation harbored no worms at that time although all had shown eggs of *Z. lunata* in the

feces at an earlier date. These 6 rats are the only ones from which all the parasites were eliminated. The number of worms remaining in the host after a long period is not related to the number of metacercariae ingested. In old infestations, the hosts which received only 30 metacercariae harbor just as many worms as those which ingested 100 or more cysts.

In the experimental ducks the parasites also occur in small numbers in the older stages of infestation, from 3 to 5 being found in infestations that are from 300 to 711 days old (Table 4). Records in the literature of the collection of *Z. lunata* from naturally infected bird hosts likewise indicate that this species after reaching maturity occurs in only small numbers. Fiscoeder (1903) in a redescription of Natterer's original material from the Vienna Museum, had for comparison 2 specimens from *Cervus dichotomus* and 2 from *Anas moschata*. Stunkard (1916) recovered 8 specimens from a duck, some of which were small and newly matured, and Price (1928) reports the presence of from 1 to 6 specimens in each of 4 species of water birds. Gower (1938), in reporting collections of *Z. lunata* from 7 species of water birds from Michigan, states, "In no case have more than four of these worms been present in any host other than the artificially infected one." He had recovered 46 immature *Zygocotyle* which were 2 weeks old from an artificially infected duck. Price (1928) reported an infestation of *Z. lunata* in a cow, *Bos taurus*, which yielded 30 specimens, but many of the worms were immature. On the basis of a comparison of relative size of acetabulum and other organs with body size, it may be concluded that the infestation in the cow was probably recently acquired and that it could have arisen from a single ingestion of metacercariae.

Little is known regarding the nature of the process of reduction in number of worms in the host. That phase of the problem, involving host-parasite reactions of a local or general nature, aside from the simple effects of crowding, is not included in the present study, but the evidence for some mechanism of host resistance is certainly apparent. Stoll (1929), working with the nematode *Haemonchus contortus*, was the first to show that following the acquirement of an initial infestation, a "self-cure" occurred, accompanied by a high degree of protection from further infection. He suggested that other helminthic infections might show a similar host response. The evidence for "self-cure" and resistance is presented for *Zygocotyle lunata* in the present studies.

Immunity. An established infestation with *Zygocotyle lunata* in ducks and in rats prevents a superinfestation with this species. Eight attempts were made to superimpose a second infestation. Table 6 shows the results of experiments involving 5 ducks and 3 rats. Following a single experimental feeding with metacercariae of *Z. lunata*, a second feeding of 50 to 150 metacercariae was given after 6 to 261 days of duration of the first infestation. The hosts were then sacrificed

after periods varying from 4 to 28 days after the second feeding. With the exception of an accidental infestation of one worm in duck 4, no worms were found from the second experimental feedings. In each case, as seen in Table 6, parasites from the second feeding would be easily identifiable and distinctly different in size from the worms actually found, all of which were from the initial experimental feeding. The number of specimens recovered in the various hosts in these planned experiments varied from 2 to 144. It may be concluded that as few as 2 mature worms of this species will make the host immune to further infestation. Further, the experiment on duck 3a shows that an infestation of 6 days duration will prevent a superinfestation, and the data on duck 4a indicate that 10 worms 261 days old will do the same. No extensive information is available as to the minimum number of worms of a given age which will be necessary to produce resistance to further infestation, but the data in Table 6 seem to indicate that a few worms of almost any age will probably be effective.

days, yielding the 6 worms of the 14-day age and one 31 days old. Four were in one caecum and 3 in the other. The results would seem to indicate that a single young worm, 17 days old, is not sufficient to produce resistance to superinfestation. This was the only case in which worms were recovered from more than a single feeding of metacercariae. In all other cases the worms obtained were of approximately the same size, any differences being easily within the range of individual variation in growth rate.

The metacercariae of a second feeding are released from their cysts and may remain in the host for as long as 4 days. Rat 8, given a second feeding 45 days after initial infestation with *Z. lunata*, was examined for eggs in the feces 4 days after the second feeding and small worms were recovered from the feces. Three were found in one medicine dropper of material from the bottom of a settling glass. They were from the second feeding of 4 days before but had not developed to a 4-day stage in growth. They were dead when recovered but their organization was

TABLE 6.

Data showing immunity to superinfestation with *Zygocotyle lunata*.

Host	First experimental feeding	Days elapsed before second feeding	Host killed		Worms recovered		Worms from second feeding
			Days after 2nd feeding	Days after 1st feeding	Age (Days)	No.	
Duck 3	10/14/37	19	28	47	47	7	0
Duck 4	10/30/37	9	5	14	14	6	0
Duck 4	10/14/37*	17	14	31	31	1	6*
Rat 8	11/15/37	45	14	59	59	23	0
Duck 3a	11/20/37	6	5	11	11	144	0
Duck 2a	11/20/37	52	4	56	56	17	0
Rat 14	11/23/37	69	23	92	92	2	0
Rat 6	10/14/37	41	10	51	51	8	0
Duck 4a	11/20/37	261	25	286	286	10	0

* Accidental infestation with 1 worm (See text).

No attempt was made to determine whether a single worm from the feeding of a single metacercaria would induce the characteristic immunity, but an accidental infection of a duck may throw some light on the probable result. Duck 4, when killed and examined, was expected to have only 14-day old worms, but it contained 6 of these and 1 worm which was obviously much older. Inspection of the data on this duck showed that it had been housed for part of a day, 31 days before, with 3 other ducks (no. 1, 2, and 3) which had just been given an experimental feeding with metacercariae of *Z. lunata*. Comparison of the single large worm obtained with other worms of known age definitely establishes it as being 31 days old. Apparently this duck (no. 4), although not purposely fed with the other 3 ducks, had accidentally picked up a cyst somewhere in the enclosure, possibly from the bill of one of the other ducks which had been fed by dropping cysts with water into their throats from a medicine dropper. This method was later abandoned in favor of placing the cysts in a pellet of bread, as described previously. Duck 4 was fed metacercariae 17 days later and then killed after 14

still intact, and when stained and mounted they were found to have progressed to a 2-day stage of development. The measurements for them are included in Table 7 which compares body size, and the sizes of acetabulum and oral sucker in metacercariae dissected from cysts and in worms of from 15 hours to 7 days of development. The 3 worms recovered from the feces of rat 8 agree closely in measurements with those of 2-day-old worms from rat 7. Apparently the reaction of immunity against superinfestation begins to be effective almost immediately after excystment of the metacercariae, since the young worms were extruded at a 2-day stage of development on the 4th day following ingestion of the metacercariae. No 4-day-old worms were found in duck 2a which was killed 4 days after a second feeding with metacercariae.

The mechanism for this resistance to superinfestation with a metazoan parasite such as *Zygocotyle* is not entirely clear. The problem has been investigated by Taliaferro (1940), Chandler (1937, 1939) and others. For the literature and a general review of the mechanism of immunity to metazoan parasites, the reader is

referred to a paper by Talianferro (1940) in which he states, "Various investigators, including the speaker (16), have stressed the fact that the immunological mechanisms, both humoral and cellular, operative against the larger parasites are identical with those operative against other infectious and antigenic non-infectious foreign materials."

2 worms from the latter host were very much larger, averaging 7.0 mm. in length and 3.2 mm. in width as compared with the average measurements of 5.0 mm. \times 2.3 mm. for the more numerous worms in rat 13. Inspection of the range in size between these two groups of parasites demonstrates strikingly the effects of crowding. A similar comparison of the data in

TABLE 7.

Comparative average measurements of specimens of *Zygocotyle lunata* of ages up to 7 days.

Age of specimen	Length	Width	Acetabulum		Oral Sucker		No. of worms measured
	in mm.	in mm.	Length in mm.	Width in mm.	Length in mm.	Width in mm.	
Metacercariae dissected from cysts	.495	.201	.171	.165	.063	.059	10
15 hrs. in Rat 22	.516	.198	.174	.164	.082	.082	10
2 days in Rat 7	.772	.260	.243	.230	.099	.105	10
4 days, from feces of Rat 8	.850	.204	.244	.211	.099	.112	3
3 days in Rat 11	.792	.306	.248	.273	.122	.106	10
5 days in Rat 1	.940	.460	.420	.400	.165	.132	10
7 days in Rat 6a	1.200	.590	.462	.442	.211	.165	10

TABLE 8.

Showing the relation between age, number and size of *Zygocotyle lunata* in rats and ducks.

Days after ingestion of metacercariae	Host	No. of worms present	No. of worms measured	Average length in mm.	Average width in mm.	Range in length in mm.	Range in width in mm.	Remarks
17	Rat 31	80	10	2.0	0.86	1.6-2.4	0.6-1.2	Immature
22	Rat 26	120	10	2.47	0.86	2.2-3.3	0.8-1.0	Immature
23	Rat 4	25	10	2.6	1.1	2.5-3.0	1.0-1.4	Immature
31	Duck 4	1	1	4.1	1.5	4.1	1.5	Immature
45	Rat 5	23	10	3.8	1.7	3.1-4.5	1.4-2.3	Some mature
47	Duck 3	7	7	6.1	3.0	5.8-6.5	2.8-3.1	All mature
51	Rat 6	8	8	5.4	2.7	4.7-6.2	2.5-2.9	All mature
56	Duck 2a	17	10	7.9	2.9	7.1-8.7	2.7-3.0	All mature
59	Rat 8	23	10	3.9	1.7	3.4-4.6	1.5-2.0	Some mature
70	Rat 15	34	10	4.1	1.7	3.4-5.4	1.5-1.9	All mature
92	Rat 13	28	10	5.0	2.3	4.2-5.8	1.7-2.7	All mature
92	Rat 14	2	2	7.0	3.2	6.6-7.5	3.1-3.3	All mature
193	Rat 18	5	4	8.2	3.0	7.0-9.5	2.8-3.3	All mature
193	Rat 21	3	3	8.6	3.1	7.0-9.5	3.0-3.2	All mature
226	Rat 60	4	4	6.0	3.1	5.5-6.4	2.7-3.4	All mature
238	Rat 52	2	2	7.3	2.9	6.9-7.7	2.5-3.3	All mature
286	Duck 4a	10	10	6.9	3.54	6.4-7.4	3.2-4.0	All mature
359	Duck 1a	2	2	7.2	3.75	7.0-7.2	3.5-4.0	All mature
424	Rat 50	1	1	10.5	3.5	10.5	3.5	All mature
507	Duck 5a	5	5	7.4	3.78	6.5-8.0	3.5-4.2	All mature
711	Rat 28	1	1	8.5	4.0	8.5	4.0	All mature
711	Duck 6a	3	3	9.1	4.65	9.0-9.2	4.6-4.7	All mature

Size and Longevity of Z. lunata. As pointed out previously, the size of worms of any given age as well as the rate of development to sexual maturity varies with the number of worms in the host. When many worms of the same age are present, the size varies more and the worms are smaller than when only a few worms of the same age are present. Table 8 shows the average size, range of size, and the number of worms present at various ages from 17 days to 711 days in rat and duck hosts. The relationship between number and size of specimens is illustrated well by the data on rats 13 and 14, both of which on the same day were fed equal numbers of metacercariae from the same snail host. Rat 13 harbored 28 worms in the cecum and rat 14 only 2. The

Table 8 for rats 6 and 8 killed 51 and 59 days after experimental infestation and yielding 8 and 23 worms respectively shows the same relationship. On the other hand worms of the same age occurring in approximately equal numbers in different hosts tend to be more uniform in size. It was observed in ducks that if one cecum contained only one worm and the other harbored several, the single worm which occupied a cecum by itself was considerably larger (8.04 mm. \times 4.25 mm.) than the other worms averaging 7.2 mm. \times 3.6 mm. from the other cecum (Duck 5a).

Rankin (1937) also pointed to the relationship between number and size of trematodes within a host and suggested that crowding may be the factor concerned. He stated, "It has been ob-

served also, that the trematodes *Brachycoelium*, *Plagitura*, and *Megalodiscus*, when present in large numbers, are usually small, though mature. Crowding of many individuals within a small area may account for small size, for when these flukes occur in small numbers, they are much larger."

The smallest sexually mature *Zygocotyle lunata* obtained from experimentally infected hosts was 3.1 mm. in length and 1.4 mm. in width, and the largest specimen measured 9.2 mm. \times 4.7 mm. The smaller worms were collected from a 45-day infestation in rat 5. From the smaller size the worms continue to grow regularly as they get older; and, as seen in Table 8, rat 50 contained a 424-day-old worm measuring 10.5 mm. \times 3.5 mm. The worms obtained after 711 days of growth in rat 28 and in duck 6a are still larger, the largest of the three from the duck being 9.2 mm. in length and 4.7 mm. in width. This represents an increase of many times in volume over the size of the worms when first sexually mature. These worms are larger than any of this species reported heretofore in the literature.

The sizes recorded in Table 8 are comparable since the same killing procedure was followed in all cases. The worms were slightly flattened on a large 2 \times 3 inch glass slide under the weight of an ordinary 1 \times 3 inch slide and killed with an aqueous saturated solution of corrosive sublimate containing 3% of acetic acid. The Table demonstrates that worms when first mature are larger in ducks than they are at a similar stage of development in rats. Ducks 3 and 2a contained mature worms 47 and 56 days old respectively which are much larger than the newly matured worms from rats 8 and 15 in which the parasites are 59 and 70 days old respectively. Some of the disparity in size is due to the fact that a greater number of worms were present in the rats. In the older worms the difference in size lessens until it disappears altogether in those of 200 days or older from the two host species. In these cases worms of the same age tend to be of the same size regardless of the host in which they developed.

Specimens of *Zygocotyle lunata* may live for more than 2 years in ducks and rats. In the rat, the length of life of *Z. lunata* is to some extent limited by the life span of the rat. Rat 28 was about 3 months old when fed metacercariae on January 31, 1938. Eggs of *Z. lunata* were collected continuously from the feces and an examination made on January 5, 1940, yielded numerous eggs. By this time, the rat, a male, was becoming quite feeble and slept most of the time. On January 12, 1940, this rat, barely able to walk across the cage, was killed and one large worm was recovered from the cecum 711 days after ingestion of the metacercariae. The rest of the intestine was not examined. The worm was very active and contained many eggs in the uterus. It extruded at least 40 normal-appearing eggs in the dish of water before it was killed and fixed. These eggs were washed and they developed normally, indicating that the old worms

are still able to reproduce and would probably live much longer. Duck 6a was also killed 711 days after a single experimental feeding with metacercariae and the 3 worms recovered were the same as the one of the same age from the rat, except that they were slightly larger.

Another duck (no. 1) was very disappointing as a subject for longevity records on *Zygocotyle*. It was given a single feeding of encysted larvae on October 14, 1937 (Table 4), and showed eggs of *Zygocotyle* in the feces after 41 days and intermittently from that time on. After about 18 months of infestation, only a few eggs were obtained in each positive fecal examination but some were collected on October 20 and 26, 1939. Two days later, October 28, the duck was killed but no worms were found. Apparently the infestation had been lost during the preceding 48 hours. The last eggs had been collected 742 days after infestation and on the 744th day the worms were gone. This does not necessarily indicate, however, that the worms live for only about 2 years.

In *Z. lunata*, the parasites apparently keep on increasing in size as long as they live, at least up to 2 years. It has been shown that many, and in a few cases all, the worms are lost long before this age is attained. Natural infestations in ducks probably carry over from one year to the next just as the experimental infestations in laboratory-raised ducks do. Gower (1938a), in a study of seasonal abundance of the parasites of wild ducks, found *Zygocotyle* in 12 of 104 ducks examined, with a slightly higher percentage of infestation during the summer and a sudden drop in the autumn. In view of the present data regarding longevity of metacercariae and of adults of *Zygocotyle*, the significance of Gower's data on seasonal abundance in this species seems doubtful. The variation reported in numbers of ducks infected at the different seasons: 17.5% in spring, 23% in summer, 4% in fall and 10% in the winter, is probably not significant. The birds may become infected with *Z. lunata* at any season but probably pick up the cysts less readily in winter when ice serves to lessen the chances for infestation. However, with the relatively long span of life of the parasite, very little difference probably occurs in the incidence of this form at different seasons.

Measurements of *Z. lunata* illustrate the need for caution in attaching much importance to size for specific diagnosis. As in some other trematodes, extreme variation exists in size of adult specimens. In the experimentally raised and genetically similar material dealt with in the present paper, old mature worms are many times larger in volume than younger, newly-matured individuals (Table 8). Measurements for the earlier stages of development are presented in Table 7. Body growth and the growth in size of organs proceed proportionately in a regular progressive manner up to the time of sexual maturity. Miller (1939) reported a decrease in size of developing *Postharmostomum larvae* in mice during the first 30 hours, and suggested

that a similar decrease probably occurs in other digenetic flukes upon entering the bodies of their definitive hosts. It is obvious from Table 7 that no such decrease occurs in *Zygocotyle*. The specimens after 15 hours in the rat are slightly larger than metacercariae, even though they have emerged from their cysts only a short time before. Some metacercariae have not yet ex-cysted after 15 hours.

Table 9 presents the comparative measure-

to specific diagnosis since trematodes commonly undergo a growth period of this sort prior to maturity. On the basis of the increase in size following sexual maturity, he emphasized the undesirability of placing too much importance on size in specific diagnosis. With reference to his measurements, he says, "The differences in size between different ages of the same fluke, as shown here, are comparable to those which have been used, at times, as a basis for indicating

TABLE 9.

Comparative measurements in mm. of stained and cleared specimens of *Zygocotyle lunata* at different ages. (Averages of several specimens in most cases.)

Age in days and host	Length	Width	Acetabulum	Oral sucker	Oral evaginations	Esophageal bulb	Anterior testis	Posterior testis	Ovary
11—Rat 3	2.14	.825	.594 × .548	.264 × .264	.099 × .066	.118 × .092	.118 × .079	.115 × .069	.060 × .046
14—Duck 4	1.87	.740	.745 × .567	.258 × .258	.085 × .070	.145 × .090	.099 × .066	.099 × .066	.055 × .050
23—Rat 4	2.60	1.12	1.06 × .878	.396 × .376	.175 × .112	.231 × .151	.455 × .231	.429 × .264	.132 × .132
31—Duck 4	4.10	1.48	1.49 × 1.06	.429 × .396	.198 × .112	.265 × .178	.330 × .198	.297 × .198	.264 × .158
45—Rat 5 (Immature)	3.33	1.28	1.06 × .807	.488 × .475	.198 × .118	.218 × .132	.396 × .297	.396 × .363	.119 × .107
45—Rat 5 (Mature)	3.10	1.70	1.05 × .825	.462 × .430	.180 × .127	.264 × .190	.660 × .264	.660 × .297	.198 × .132
47—Duck 3	6.10	3.00	1.59 × 1.06	.521 × .462	.205 × .129	.328 × .219	1.09 × .512	.972 × .549	.476 × .264
51—Rat 6	5.48	2.65	1.30 × 1.06	.613 × .628	.264 × .158	.383 × .208	1.04 × .552	1.04 × .594	.445 × .255
92—Rat 14	7.05	3.20	1.48 × 1.19	.552 × .637	.212 × .170	.382 × .255	.892 × .425	.935 × .595	.425 × .297
193—Rat 21	8.23	2.97	1.59 × 1.27	.689 × .637	.243 × .212	.403 × .218	1.10 × .743	1.18 × .743	.637 × .254
359—Duck 1a	7.20	3.75	1.48 × 1.48	.552 × .552	.212 × .170	.382 × .245	1.06 × .425	1.06 × .425	.637 × .255
507—Duck 5a	7.71	4.07	1.82 × 1.48	.595 × .595	.212 × .191	.362 × .232	1.44 × .595	1.57 × .637	.722 × .275
711—Duck 6a	9.10	4.65	1.91 × 1.48	.660 × .627	.212 × .170	.380 × .255	1.10 × .510	1.06 × .552	.637 × .264

ments of worms varying in age from 11 to 711 days. The measurements are averages of several worms in most cases and are taken from similarly stained and cleared whole mounts. It is apparent that size of body and size of the contained organs increases proportionately up to sexual maturity. After sexual maturity is attained, however, the body organs do not continue to increase in size significantly in proportion to the increase in gross size of the worm as it becomes older and larger. Some individual variation occurs, but the apparent slight increase in size of some organs, as the acetabulum, does not parallel the rate of increase shown in total body measurements (Figs. 20-25). A comparison of body size and organ size in specimens 47 and 51 days old with those of specimens 92 to 711 days old (Table 9) shows little significant growth in size of organs but a very considerable increase in gross size.

Miller (1939) made observations on the rate of growth in *Postharmostomum* and described an increase in both length and width between worms which are 400 hours old, measuring 3.07 mm. by 1.09 mm., and worms 1,100 hours old which are 3.99 mm. long and 1.32 mm. in width. The worms are apparently sexually mature at 400 hours. He presented no data on size for ages intermediate between 400 and 1,100 hours, and did not report the range of variation among the specimens. The average measurements showing an increase in length and width of the worms during the stages preceding sexual maturity (before 400 hours) are not significant with respect

different species." While this may be true, it should be pointed out that the reported increases in length of 30 per cent., and in width of 17 per cent., following sexual maturity in *Postharmostomum*, are not greater than the variation in size which may occur in different specimens of *Zygocotyle* of the same age collected from a single host animal. In *Zygocotyle*, the 70-day-old worms collected from rat 15 (Table 8) varied in length from 3.4 mm. to 5.4 mm., the longer specimens being 58 per cent. greater in length than the smaller ones. Similarly the 92 day old specimens from rat 13 exhibit a 38 per cent. difference. As shown earlier, a wider variation in size of worms occurs in the hosts which harbor a large number of specimens than in those which contain relatively few. In *Zygocotyle*, worms of a given age are larger when only a few are present than when many have developed together in the same host. The possibility exists that this relationship may be a factor in the size difference between 400 and 1,100 hour worms in *Postharmostomum*, since 28 flukes of the 400 hour group were present in the host animal, while only 5 were found in the mouse which yielded the larger 1,100 hour worms. In view of the relationships between number, size and age of specimens demonstrated in *Zygocotyle*, the data given by Miller for *Postharmostomum laruei* do not justify the conclusions presented by him regarding trematodes in general.

During the course of the infestations with *Zygocotyle*, frequent fecal examinations for eggs of the parasite were conducted. Interesting

differences appear in the results obtained from feces of rats and ducks. The same procedure was followed in all cases. Fecal samples were broken up in water and strained through a fine wire screen into a settling dish in which the material was then washed several times by the decanting method. The eggs were collected under a binocular dissecting microscope. In every fecal examination of rats infected with mature *Zygocotyle*, eggs were obtained. Rat 28 was examined more than 50 times over a period approaching two years. The number of eggs collected from 8 fecal pellets varied from 650 in the early months of the infestation to as few as 25 during the last few weeks of the life of the rat. Some were always present. Feces of infected ducks, however, did not always contain eggs. For some reason not clear to the writer, a bird would apparently be negative, and then a week or two later, eggs would again be present. Daily fecal examinations sometimes failed to yield eggs for periods up to 2 weeks, after which eggs would be plentiful again for a similar period in daily collections of feces. Of 78 recorded examinations of fecal samples from duck no. 1, 43 were positive and 35 were negative, but the significant feature is that the feces were often consistently negative or positive for periods of from 8 to 13 successive days. Although a periodicity in egg production for *Zygocotyle* in ducks is suggested by such data, it apparently does not occur since it certainly does not exist in the rat host. The results cannot be accounted for by loss of worms and subsequent reinfestation, because no opportunity was afforded for reinfestation. The only explanation that can be offered at present is the element of chance combined with the peculiar action of the ceca in ducks. Fecal samples from other infected ducks were similarly negative from time to time for *Zygocotyle* eggs, although the hosts were unquestionably infected. The data are not sufficiently complete to draw any conclusions other than that failure to find eggs of trematodes living in the ceca of ducks, after only a few fecal examinations, does not necessarily indicate that the bird is not infected. Caution must be exercised in using such ducks for feeding experiments in life history studies.

THE ADULT.

The morphology of *Zygocotyle lunata* has been adequately described by Fiscoeder (1903), Stunkard (1917), Price (1928) and Gower (1938). Since the tables presented in the present work include comparative measurements and other information concerning variation within the species, no detailed description of the adult is given. Figures 20-25 are photomicrographs of whole mounts at various stages of development, from 5 days to 711 days old, showing the relation between size of organs and size of the body. Figures 23 and 24 illustrate, among other things, the fact that the acetabulum does not increase in size in proportion with increase in size of body as the worms grow older and larger, but is proportionately smaller in older than in younger

worms. The actual sizes and ages of these specimens is given in the explanations of the figures and the average sizes for the organs appear in Table 9.

Stunkard (1917) transferred *Amphistoma lunatum* to the genus *Zygocotyle* and erected a new subfamily, with *Zygocotyle* as type genus, to contain it. The subfamily Zygocotylineae was first named by Ward (1917). Bhalerao (1931) described a new genus and species, *Stunkardia dilymphosa*, and placed it with *Zygocotyle* in the subfamily Zygocotylineae. On the basis of the structure of *Stunkardia dilymphosa*, Bhalerao found it necessary to modify the definition of the subfamily. He described two pairs of lymph vessels in the new species, as indicated by the specific name, and therefore, in the new diagnosis he includes, "Lymphatic system with a pair of dorsal and a pair of ventral lymph canals." The lymph system of *Zygocotyle*, the type genus, had not been described at that time. Willey (1933) showed that *Zygocotyle* possesses only a single pair of main lymph channels, and pointed out that, "The citation with respect to the lymph system in the subfamily must be modified or else eliminated entirely from the definition." Furthermore, in view of the report by Price (1928), showing *Bos taurus* as a host of *Zygocotyle*, and on the basis of the experimental infestations obtained in a sheep and in rats by the present author, that part of Bhalerao's diagnosis concerning the host relationships of the subfamily Zygocotylineae, "Parasites of birds and reptiles," must therefore be changed to include parasites of mammals. Although Näsmark (1937) cited the work of Price (1928), showing that *Zygocotyle* occurs in the cow, supporting the earlier host record by Diesing (1836) of this species from a deer, he apparently did not accept it as valid. He stated (p. 436), "Hitherto known definitely only from ducks in America. A specimen from *Bos taurus* may be wrongly labelled (?)." The experimental infections in the rat and sheep accomplished in the present work certainly leave no further doubt that *Zygocotyle* occurs in mammals as well as in birds. In his diagnosis of the subfamily Zygocotylineae, Näsmark (1937) stated (p. 444), "So far as is known with certainty they parasite (sic) only in American ducks." Nevertheless he cited the work of Bhalerao (1931) who placed *Stunkardia dilymphosa*, from a reptile, in the subfamily Zygocotylineae. It is not clear whether Näsmark inferred that *S. dilymphosa* does not belong in the subfamily or whether the statement was made in error. If *S. dilymphosa* should not be included, as seems likely to the present writer, then *Zygocotyle lunata* is the only species as yet known in the subfamily Zygocotylineae.

SUMMARY.

Beginning with cercariae (*C. poconensis* Willey, 1930) from naturally infected snails of the species *Helisoma antrosomum*, the complete life cycle of *Zygocotyle lunata* was demonstrated in the laboratory. The cercariae encyst in the open

and metacercariae fed to laboratory-raised rats, ducks and a sheep developed into adult worms. Eggs collected from feces were embryonated and the miracidia penetrated laboratory-raised *Heliosoma antrosomum* from which cercariae emerged within from 32 to 49 days after exposure. The morphology and activities of the miracidia are described. In the snail the miracidium metamorphoses into a sporocyst which produces rediae. Some of the rediae contain a single daughter redia at the anterior end as well as cercariae developing at the same time in the same larva. Other rediae contain only young cercariae. It is probable that each redia produces one daughter redia and proceeds from that time on to produce cercariae only. This explains the presence of rediae of all sizes during all stages of the infestation which persists for more than 10 months in the snail. The sporocyst becomes exhausted and disappears soon after the first cercariae are shed.

Cercariae leave the redia while still immature and continue their development in the lymph spaces of the snail, after which they emerge and encyst in the open. Encysted metacercariae are infective immediately and some are still infective when fed to rats after 138 days in the laboratory at room temperature. They will withstand freezing temperatures but are not viable if left out of water for 48 hours at room temperature. No development occurs in the cyst.

In the rat the metacercariae encyst in the cecum and develop to maturity. They are normally parasites of the cecum and have been reported from the ceca of various water birds, a deer and a cow. The present experimental infestations in the rat and sheep constitute new host records for *Zygocotyle*. Sexual maturity of *Z. lunata* is attained faster in ducks (41-44 days) than in rats (46-61 days), and the rate of development is influenced by the number of worms present, more time being required when many worms are present. As the age of the infestation increases, the number of worms is reduced and only a few persist for long after sexual maturity is reached. The host usually eliminates most of them within the first 3 months and retains only 1 to 5 thereafter. An established infestation of *Z. lunata* in rats and ducks prevents a superinfestation with this species.

Size of worms varies with the number present. When many worms of the same age are present, the size varies more and the flukes are smaller than when only a few of the same age are developing together. The data demonstrate the effects of crowding. *Z. lunata* may live for more than 2 years in rats and ducks, and following sexual maturity the worms continue to increase in size. The smallest sexually mature worm obtained experimentally was 3.1×1.4 mm. and the largest measured 9.2×4.7 mm. when 711 days old. Although gross size increases greatly, the sizes of organs in the body do not increase proportionately. The value of size as a species difference in trematodes is discussed. Regular

fecal examinations of ducks infected with *Z. lunata* often failed to show eggs of the parasites which were resident in the ceca. Feces of infected rats always yielded eggs. Ducks should not be considered negative for worms living in the ceca after only a few negative fecal examinations.

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EXPLANATION OF THE PLATES.

PLATE I.

Photomicrographs of eggs and miracidia of
Zygocotyle lunata.

- Fig. 1. Egg, living, from feces. Length, 0.145 mm.
 Fig. 2. Eggs, showing variation in shape and size.
 Fig. 3. Embryo after 13 days of development.
 Fig. 4. Embryo after 18 days of development.
 Fig. 5. Embryo after 21 days of development.
 Fig. 6. Miracidium, living, slightly flattened under a coverglass. Length, 0.210 mm.
 Fig. 7. Miracidium, whole mount of silver impregnated specimen, showing entire thickness. Length, 0.191 mm.
 Fig. 8. The same miracidium as in figure 7, with higher initial magnification showing critical focus on the upper surface. Length, 0.191 mm.

PLATE II.

Free-hand drawings of some larval stages of
Zygocotyle lunata.

Abbreviations.

- ap, apical papilla
 br, dorsal nerve mass
 ce, cercaria
 ci, cilia
 cn, epidermal cell nucleus
 dr, daughter redia
 ed, excretory collecting duct
 ep, excretory pore
 es, eye-spots
 fl, flame cell
 gb, germ ball
 gc, germ cell
 gn, 'gut' nucleus
 in, intestine
 pg, 'primitive gut'
 ph, pharynx
 re, redia
 sc, subepithelial cell nucleus
 sp, aperture for sensory papilla
 T1, Epidermal cell of 1st tier
 T2, Epidermal cell of 2nd tier
 T3, Epidermal cell of 3rd tier
 T4, Epidermal cell of 4th tier
 ve, vesicle

- Fig. 9. Miracidium from dorsal aspect; reconstruction from observations on numerous living and fixed specimens. Average length, 0.195 mm.
 Fig. 10. Reconstruction of sporocyst from sections of experimentally infected *Helisoma antrosomum*, 28 days after penetration of the miracidium. Length, 0.305 mm.

- Fig. 11. Young redia containing single, large daughter redia, from living specimen. Length, 0.330 mm.
 Fig. 12. Older redia containing single young daughter redia and several developing cercariae; 25 days after penetration of the miracidium, living specimen. Length, 0.860 mm.
 Fig. 13. Redia, containing active, older daughter redia which is ready to emerge, and several developing cercariae; from living specimen in snail crushed 47 days after penetration of the miracidium. Length, 0.792 mm.

PLATE III.

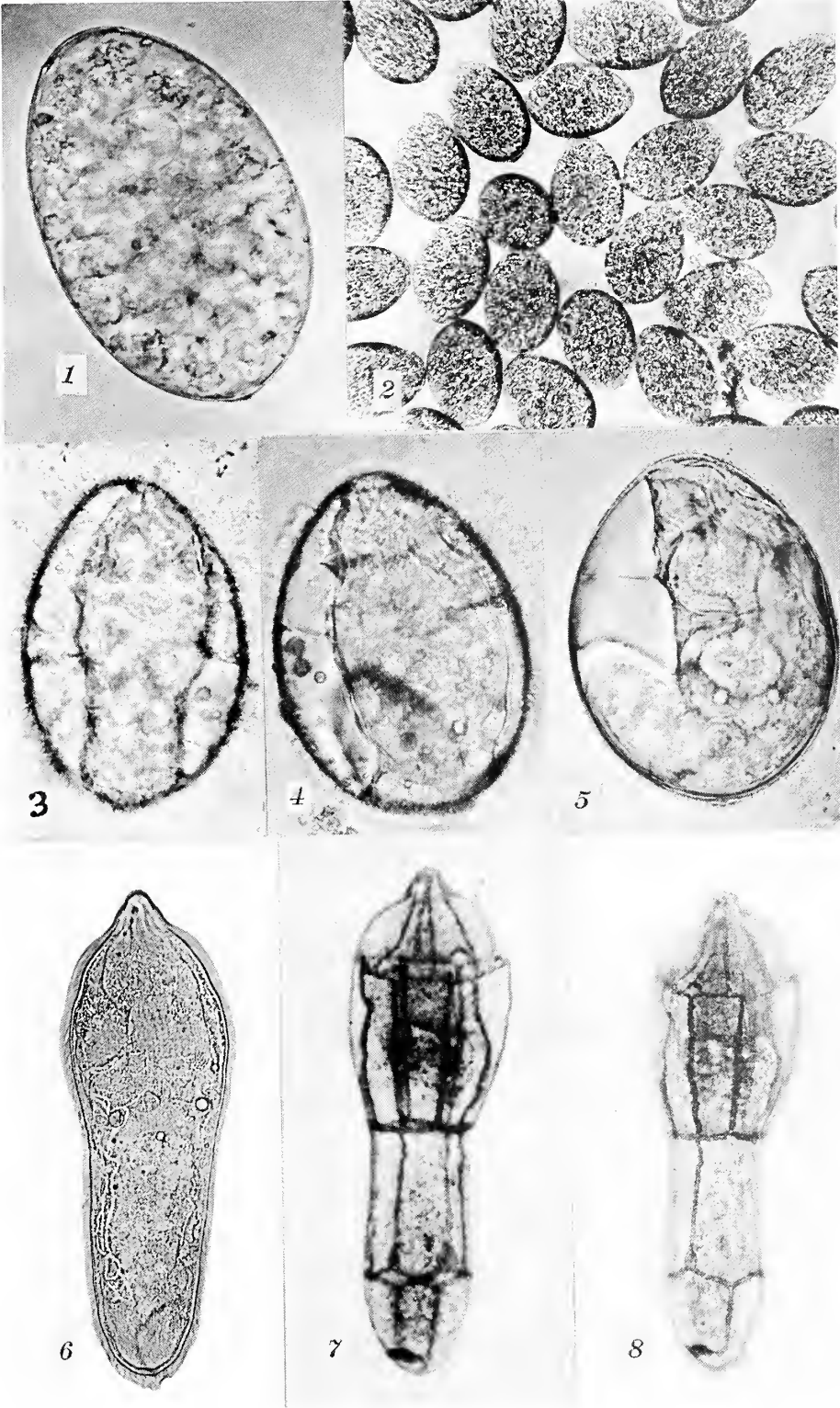
Photomicrographs of various stages in the life history of *Zygocotyle lunata*.

- Fig. 14. Section of sporocyst reconstructed in fig. 10. Note pharynxes of 2 rediae and portions of intestine of 2 others.
 Fig. 15. Redia, living, containing developing cercariae and germ balls. Length, 0.775 mm.
 Fig. 16. Ventral aspect of mature cercaria, living, under medium pressure of coverglass. The tail is still attached but out of focus. Note branched excretory collecting ducts as outlined by excretory concretions. Length, 0.990 mm.
 Fig. 17. Whole mount of fixed and stained cercaria from ventral side, killed under slight pressure. Length, 0.660 mm.
 Fig. 18. Encysted metacercariae attached to the surface of the shell of a snail. Average diameter, 0.289 mm.
 Fig. 19. Ventral aspect of whole mount of a 10-day old metacercaria dissected from its cyst. Length of specimen, fixed and stained, 0.489 mm.
 Fig. 20. Ventral aspect of young immature adult after 5 days of development in rat 1. Length, 0.924 mm.

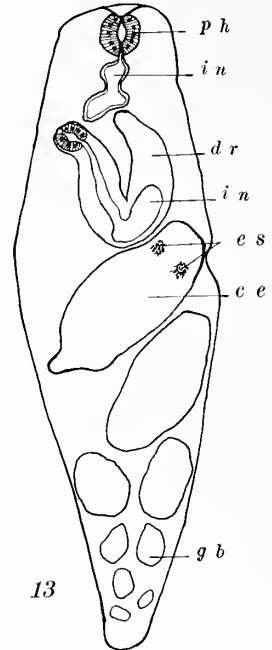
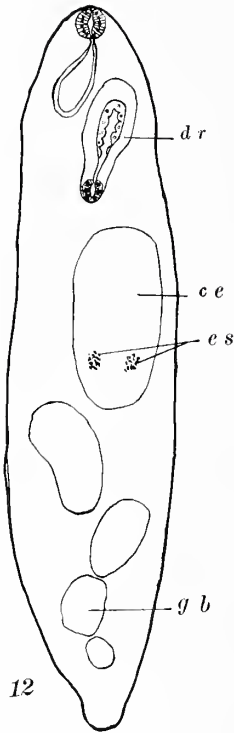
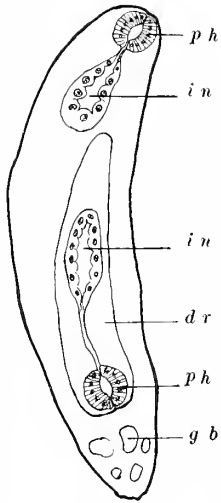
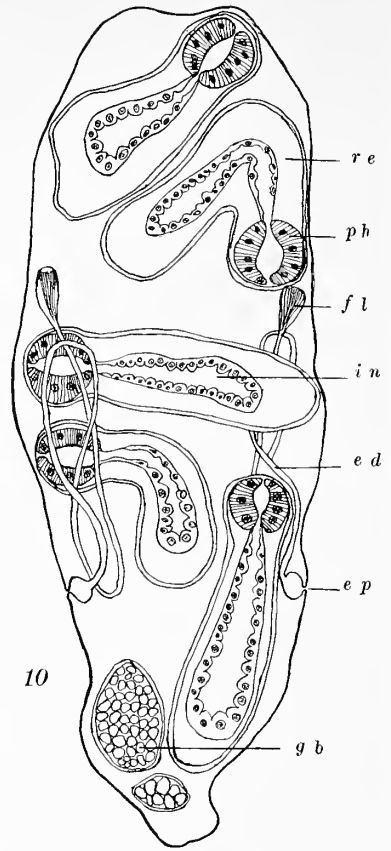
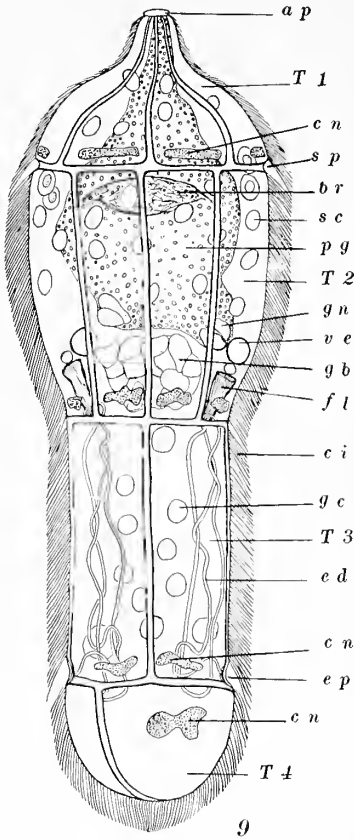
PLATE IV.

Photomicrographs of whole mounts of fixed and stained specimens of *Zygocotyle lunata* at various stages of development in the final host.

- Fig. 21. Ventral aspect, after 11 days in rat 3. Length, 2.21 mm.
 Fig. 22. Ventral aspect, after 14 days in duck 4. Length, 2.12 mm.
 Fig. 23. Ventral aspect, after 23 days in rat 4. Length, 3.04 mm.
 Fig. 24. Ventral aspect, after 51 days in rat 6. Length, 6.07 mm.
 Fig. 25. Dorsal aspect, after 711 days in duck 6a, photographed by reflected light. Length, 9.0 mm.



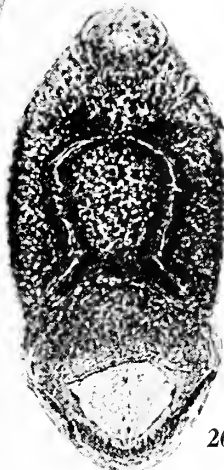
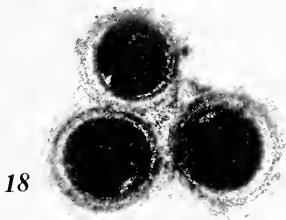
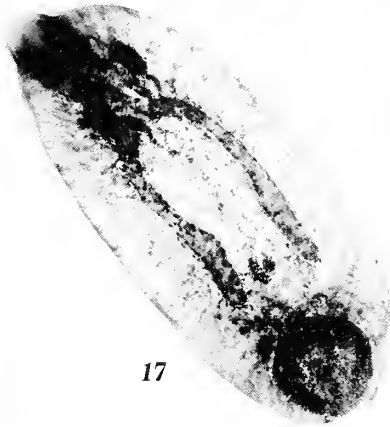
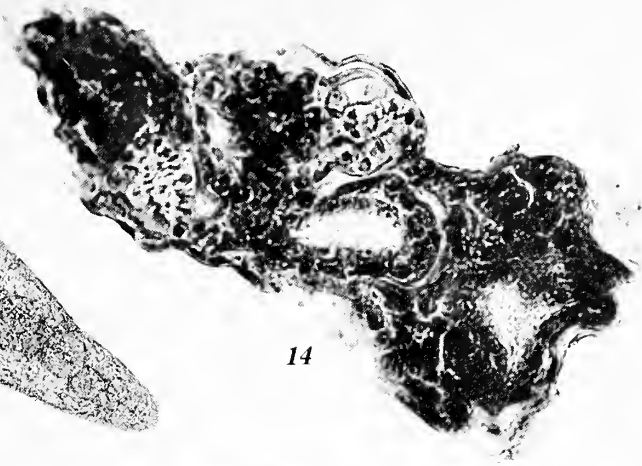
ZYGOCOTYLE LUNATA.



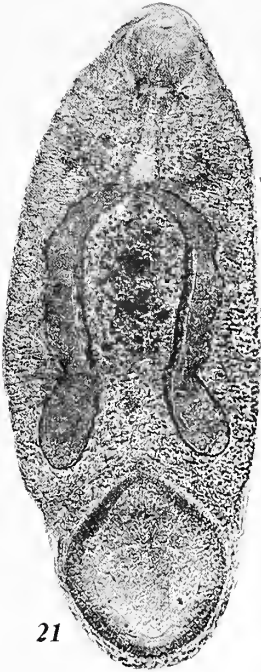
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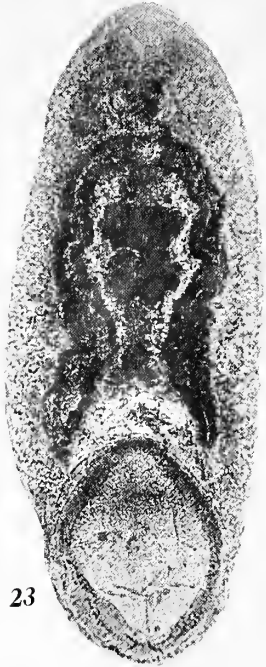
ZYGOCOTYLE LUNATA.



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ZYGOCOTYLE LUNATA.

14.

**Eastern Pacific Expeditions of the New York
Zoological Society. XXIV.**

**Fishes from the Tropical Eastern Pacific.
[From Cedros Island, Lower California, South to the Galápagos
Islands and Northern Peru.]**

Part 1. Lancelets and Hag-fishes.¹

WILLIAM BEEBE

&

JOHN TEE-VAN

Department of Tropical Research, New York Zoological Society.

(Text-figures 1 & 2).

[This is the twenty-fourth of a series of papers dealing with the collections of the Eastern Pacific Expeditions of the New York Zoological Society made under the direction of Dr. William Beebe. The present paper is concerned with specimens taken on the Templeton Crocker Expedition (1936), and the Eastern Pacific Zaca Expedition (1937-1938). For data on localities, dates, dredges, etc., of these two expeditions, refer to *Zoologica*, 22: 33-46 (Templeton Crocker) and *Zoologica*, 23: 278-298 (Eastern Pacific Zaca).]

This series of papers on fishes and fish-like animals will list the species known from the region; those represented by specimens taken on our own expeditions will be treated more extensively. As far as the unrepresented forms are concerned, field characters, size, original and regional references, and whenever possible an illustration, are given for each species.

Class LEPTOCARDII.

Order Cirrostomi.

Family BRANCHIOSTOMIDAE.

Branchiostoma Costa, 1834.

KEY TO TROPICAL EASTERN PACIFIC SPECIES.

- 1a. 68 to 74 myotomes (California to Panama).
.....*californiense*.
1b. 78 to 81 myotomes (Peru, Chile and the Galapagos Islands (Albemarle)).....*elongatum*.

Branchiostoma californiense Andrews.



¹ Contribution No. 621, Department of Tropical Research, New York Zoological Society.

Range: Monterey Bay, California, to Chame Point, Panama, in sand from depths of one foot to thirty-five fathoms. (Mexico: San Luis Gonzales Bay and Arena Bank, Gulf of California, Cape San Lucas; Nicaragua: Corinto; Costa Rica: Piedra Blanca Bay and Gulf of Dulce; Panama: Chame Point.)

Description: Dorsal ray-chambers 312 to 374 (average 337); preanal chambers about 50; higher dorsal chambers five to eight times as high as long; dorsal fin one-fifth to one-eighth as high as body; anus located far behind middle of lower lobe of caudal fin; distance from atriopore to origin of lower caudal lobe contained from .8 to 2 times in distance thence to anus; preatrioporal length 2.65 to 3.3 times the postatrioporal length; myotome formula 43 to 48 + 16 to 19 + 8 to 10 = 68 to 74; gonad pouches 27 to 36 (average 33); distance from tip of rostral fin to anal sphincter 13.8 to 16.3 times in total length. (Description from Hubbs, 1922; as our specimens are immature. Illustration from specimen 25,482a, 29.4 mm.)

Color: Creamy white; several of our specimens showed a conspicuous brown band across the center of the snout.

Size: Mature specimens 58 to 83.5 mm., our immature individuals were 17 to 48.8 mm.

Local Distribution: Our specimens were dredged in sand beneath depths of water ranging from 12 inches to 210 feet. This latter record of 35 fathoms on Arena Bank is the deepest known, 6.5 fathoms being the deepest hitherto recorded.

Abundance: The nine specimens were dredged in four widely separated localities. The species is doubtless to be found in all suitable localities throughout the range under discussion.

Food: A dark area in the intestine of an

Amphioxus from the Gulf of Dulce, Costa Rica, resolved into a mass of diatoms of several species.

Breeding: All of our specimens are immature; they present, however, the recognizable characters of *californiense*. The 48.8 mm. individual from 35 fathoms had 358 dorsal ray-chambers and was quite free of gonads, while its 37 mm. companion from the same haul showed 31 gonads.

Study Material: 9 specimens. Mexico: Arena Bank, Lower California, Station 136:D-30, 35 fathoms, 4 (25,482), 20 to 48.8 mm., May 1, 1936, dredged; Nicaragua: Corinto Harbor, Station 200:D-22, 1.5 fathoms, 2 (27,700), 17 and 24 mm., Jan. 7, 1938; Costa Rica: Piedra Blanca, Station 218:D-2, 5 fathoms, 2 (28,211) 19 and 30 mm., Feb. 5, 1938, dredged; Golfito, Gulf of Dulce, 12 inches deep, 1 (28,649), 36 mm., March 6, 1938, sifted from sand in shallow tidal stream.

References: *Branchiostoma* sp., Cooper, J. G., in Cronise, T. F., Natural Wealth of California, 1868: 498 (First mention of a branchiostomid on Pacific Coast).

Branchiostoma lanceolatum, Lockington, W. N., *Proc. Acad. Nat. Sci., Phila.*, 1881 (1882): 114 (Angeles Bay, Lower California). Pellegrin, J., *Bull. Mus. Hist. Nat. Paris*, 7, 1901: 163, 167 (Several specimens 55-65 mm., from Los Angeles Bay, Lower California).

Branchiostoma californiense, Andrews, E. A., *Studies Biol. Laboratory Johns Hopkins Univers.*, 5, 1893: 238 (San Diego, California). Jordan, D. S. & Evermann, B. W., *Fishes North and Middle America*, 1, 1896: 4 (San Luis Gonzales Bay, Gulf of California). Hubbs, C. L., *Occ. Pap. Mus. Zool., Univ. Michigan*, 105, 1922: 11 (redescription of species). Meek, S. E. & Hildebrand, S. F., *Marine Fishes of Panama*, 1, 1923: 28 (Range extended to Chame Point, Panama; 61 specimens 20 to 37 mm., "tentatively referred to this species in the absence of comparative material"). Ulrey, A. B., *Journ. Pan-Pac. Res. Inst.*, 4 (4) 1929: 2 (Cape San Lucas, Gulf of California).

Discussion: The California Amphioxus, *Branchiostoma californiense*, presents an interesting comparison with three species of the western Atlantic, *virginiae*, *floridiae* and *caribaeum*. Its maximum length is one-third (34%) greater than the average of the other three. It shows a decided increase in four categories of metameral characters: dorsal ray chambers 16%, preanal chambers 25%, myotomes 18% and gonads 24%. That this is not wholly the result of a larger organism in general (55 as compared with 83.5 mm. in maximum length) is proved by a corresponding comparison of the three Atlantic species with *elongatum*, which replaces *californiense* from the Galápagos to Chili. The percentage of the maximum length of this more southern form is only 20% over the Atlantic species, but in preanal ray-chambers it is 46% numerically superior, in myotomes 27%, while it possesses 32% more gonads than the Atlantic species.

Branchiostoma elongatum (Sundevall).

Range: Peru (Chincha Islands), Chile and the Galápagos Islands (Albemarle).

Description: Dorsal ray-chambers numerous, but not accurately countable, and moderately high; preanal chambers about 65 to 75, much more numerous than in other species of *Branchiostoma*; anus located slightly in advance of middle of lower caudal lobe; distance of atriopore to origin of this fin lobe contained 1.3 times in total distance behind this point. Preatrioporal length 2.4 to 2.6 times the postatrioporal length; myotomes very oblique; the formula 48 to 51 + 18 + 12 or 13 = 79 to 81. Gonad pouches 37; oral hood reduced in size, as in *B. californiense*. (Hubbs, 1922: 13.)

Study Material: None.

References: *Amphioxus elongatus*, Sundevall, C. J., *Oefvers. Vet. Akad. Forh.*, 9, 1852: 147 (description; type locality, Chincha Islands, Peru). Kirkaldy, J. W., *Quart. Journ. Microsc. Sci.*, 37, 1895: 303.

Branchiostoma elongatum, Sundevall, C. J., *Oefvers. Vet. Akad. Forh.*, 10, 1853: 12 (Chincha Islands, Peru). Steindachner, F., *Fauna Chilensis*, 1898: 334 (Cavancha Bay, Iquique, Chile). Herdman, W. A., *Cambridge Nat. Hist.*, 7, 1904: 137 (Myotomes 49-18-12, Peru). Snodgrass, R. E. & Heller, E., *Proc. Wash. Acad. Sci.*, 6, 1905: 342 (Galápagos Islands, 13 specimens, the largest 20 mm.). Goldschmidt, R., *Zool. Anz.*, 29, 1905: 132-133 (Peru). Hubbs, C. L., *Occ. Pap. Mus. Zool., Univ. Mich.*, 105, 1922: 13 (diagnosis).

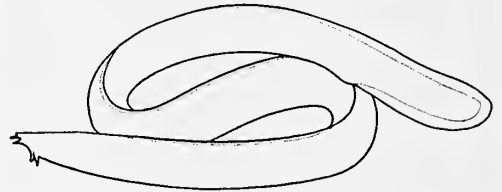
Class CYCLOSTOMI.

Order Hyperotreta.

Family MYXINIDAE.

Myxine Linnaeus, 1758.

Myxine circifrons Garman.



Range: Gulf of Panama; known from 20 miles W. × S. of Caracoles Point, in 730 fathoms.

Field Characters: Eel-shaped eyeless animals with a series of barbels about the mouth. Upper teeth 13 on each side, lower teeth 11 on each side, of which the anterior three of each upper and the anterior two of each lower series are confluent.

Color uniform black; head lighter anteriorly.
(Illustration after Garman, 1899; 470 mm.)

Size: Grows to 18½ inches.

Study Material: None.

References: *Myxine circifrons*, *Mem. Mus.*

Comp. Zool., 24, 1899: 344, Plate 68, figs. 1-4
(original description, color, figures of entire
animal, head, heart and gills; type-locality,
Albatross station 2395, 7° 30' 36'' N., 78° 39' W.,
Gulf of Panama in 730 fathoms. Type in *Mus.*
Comp. Zool.).



15.

**Eastern Pacific Expeditions of the New York
Zoological Society. XXV.**

**Fishes from the Tropical Eastern Pacific.
[From Cedros Island, Lower California, South to the Galápagos
Islands and Northern Peru.]**

Part 2. Sharks.¹

WILLIAM BEEBE

&

JOHN TEE-VAN.

Department of Tropical Research, New York Zoological Society.

(Plates I & II; Text-figures 1-34).

[This is the twenty-fifth of a series of papers dealing with the collections of the Eastern Pacific Expeditions of the New York Zoological Society made under the direction of Dr. William Beebe. The present paper is concerned with specimens taken on the *Noma* Expedition (1923), the *Arcturus* Oceanographic Expedition (1925), the *Antares* Expedition (1933), the Templeton Crocker Expedition (1936) and the Eastern Pacific *Zaca* Expedition (1937-1938). For data on localities, dates, dredges, nets, etc., of the second, fourth and fifth of these expeditions, refer to *Zoologica*, Vol. 8, No. 1, pp. 1-45 (*Arcturus*); *Zoologica*, Vol. 22, No. 2, pp. 33-46 (Templeton Crocker), and *Zoologica*, Vol. 23, No. 14, pp. 278-298 (Eastern Pacific *Zaca*).]

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¹ Contribution No. 622, Department of Tropical Research, New York Zoological Society.

² The general arrangement adopted here is that of E. Grace White (*Bull. Amer. Mus. Nat. Hist.*, 74 (2), 1937: 36-38).

Superfamily Squaloidea	
Family Squalidae	120
<i>Centroscyllium nigrum</i>	120
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Suborder Squatinida	
Superfamily Squatinoidea	
Family Squatinidae	121
<i>Squatina californica</i>	121

INTRODUCTION.

This paper deals with sharks collected in tropical eastern Pacific waters on five expeditions of the Department of Tropical Research of the New York Zoological Society under the direction of Dr. William Beebe. As an aid to future students we have included all species that have been recorded from the eastern tropical Pacific.

The geographical boundaries of the region under consideration in this paper and which we call the "tropical eastern Pacific" are as follows: The coastal waters of North and South America from Cedros Island off the west coast of Lower California, and the Gulf of California, southward to northern Peru, including off-shore islands such as the Galápagos and Revillagigedo groups, and Clipperton, Cocos and Malpelo Islands.

As far as references are concerned, we have listed the original reference with the type locality, and references referring to the region under discussion. Additional references have been added, however, whenever their inclusion was felt necessary. Some of the more commonly cited papers have been referred to by name and not by publication, serial and page numbers; the full references will be found on page 122. Synonyms of nominal forms described from the region are included, but not necessarily those from extralimital localities.

Thirty-three sharks are reported from the waters of the tropical eastern Pacific as delimited. As might be expected, most of these species are forms that live dominantly in warm waters. But surprisingly enough a number of species usually found widely distributed in warm waters of other parts of the world and that might be expected to be in our region, are unreported from the area under consideration. Whether this absence is an actual one, or whether it is the result of comparatively few collections having been made in the region, is a question. Under any circumstances these sharks must be uncommon as there have been a sufficient number of collections made in the region to have produced at least one specimen of these species.

We are indebted to Dr. Leonard P. Schultz of the U. S. National Museum, Mr. John T. Nichols of the American Museum of Natural History, Prof. Albert E. Parr of the Peabody Museum, Yale University, and Dr. H. B. Bigelow and Mr. William C. Schroeder of the Museum of Comparative Zoology, Cambridge, for the loan of material and for valuable information; to Miss Janet Wilson for inking the outline drawings and

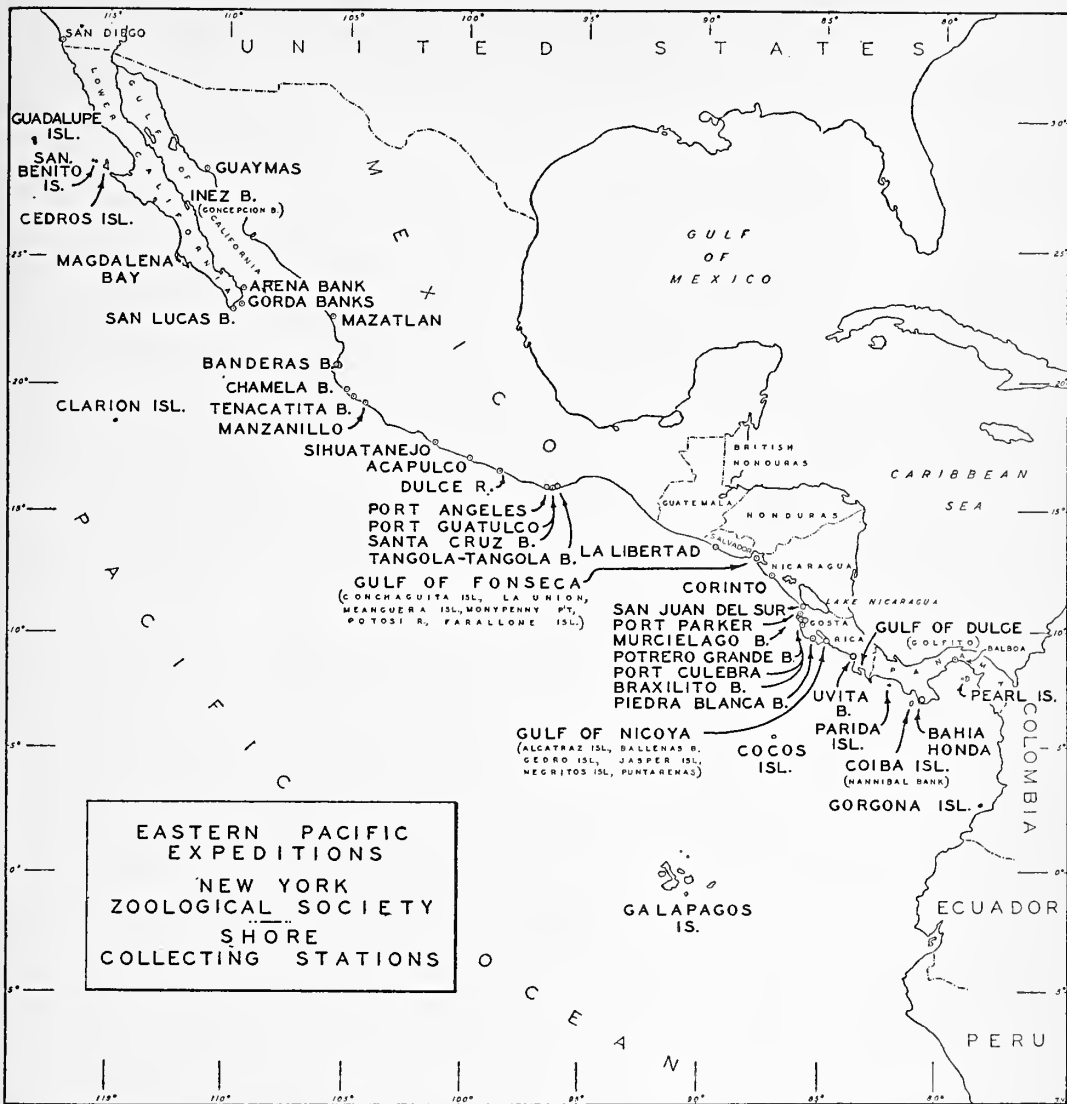
to Miss Jocelyn Crane and Mr. Toshio Asaeda for photographs.

Key to the Families of Sharks of the Tropical Eastern Pacific³

1. Body not markedly depressed or expanded laterally, except in the case of the hammer-head sharks, where the head only is expanded 2
Body depressed, usually widely expanded laterally. 16
2. Gill-openings 6 or 7 on each side, a single dorsal fin. 3
Gill-openings 5 on each side, two dorsal fins. 4
3. Body greatly elongate, almost eel-shaped; mouth anterior. *Chlamydoselachidae*, p. 96
Body moderately elongate; mouth inferior
Hexanchidae, p. 96
4. Anal fin present. 5
Anal fin absent. 15
5. Dorsal fins provided with a strong spine anteriorly. *Heterodontidae*, p. 117
Dorsal fins without spines anteriorly. 6
6. First dorsal fin over or behind the pelvic fins. 7
First dorsal fin in advance of the pelvic fins. 8
7. Nostrils confluent with the mouth; tail directed upward somewhat from the body
Orectolobidae, p. 96
Nostrils not confluent with the mouth; tail not directed upward from the body
Scylliorhinidae, p. 99
8. Caudal peduncle with a keel on each side; caudal fin lunate. 13
Caudal peduncle without a keel on each side; caudal fin not lunate, its upper lobe two or more times the length of the lower. 9
9. Tail exceedingly long, forming about one-half of the total length; eyes without nictitating membranes or folds. *Alopiidae*, p. 97
Tail moderately developed, forming less than one-third the total length; eyes with nictitating membranes or folds. 10
10. Head hammer- or kidney-shaped, its sides extended laterally. *Sphyrnidae*, p. 114
Head normally formed, without lateral extensions. 11
11. More than two rows of teeth in use; teeth in bands or pavement. 12
One or two rows of teeth in use; teeth compressed, triangular, not in bands or pavement
Galeorhinidae, p. 104
12. Teeth pavement-like, the cusps flattened
Mustelidae, p. 102
Teeth not pavement-like, each tooth with three to five sharp cusps. *Triakidae*, p. 100
13. Last gill-opening entirely in front of the pectoral fins. 14
Last gill-opening above the base of the pectoral fins; size enormous. *Rhineodontidae*, p. 97
14. Gill-openings very large, extending from the back and nearly meeting under the throat; teeth very small; size enormous
Cetorhinidae, p. 98
Gill-openings moderate, not as above; teeth very large and sharp. *Isuridae*, p. 98

³In addition to the families found in the eastern tropical Pacific, a few other families have been included that have representatives immediately north and south of the province here treated. These have been inserted on the presumption that they might be found sometime within the area.

The keys in this paper are based only upon the species that are found within the area under consideration; they will not necessarily be found to apply to sharks of the same genera in other parts of the world.



Text-figure 1.

Principal localities in the tropical eastern Pacific where collections were made by the Department of Tropical Research of the New York Zoological Society.

- 15. Dorsal fins each provided with a spine
Squalidae, p. 120
- Dorsal fins without spines *Scymnorhinidae*, p. 121
- 16. Gill-openings on sides of body; anterior extension of the pectoral fins separated from the

neck by a deep notch in which lie the gill-openings.....*Squatinae*, p. 121

Gill-openings on under side of the body. (Rays and mantas; these will be treated in a succeeding paper.)

Systematic Account.

Family CHLAMYDOSELACHIDAE.

Chlamydoselachus Garman, 1884.

Chlamydoselachus anguineus Garman.

Unrecorded from our region, although Garman⁴ mentions the following: "This shark is one that may confidently be expected to appear in future collections from the region about the Galápagos."

Family HEXANCHIDAE.

Hexanchus Rafinesque, 1810.

Hexanchus griseus, the six-gilled shark, is one of a number of sharks unrecorded from the tropical eastern Pacific, but reported from immediately north and south of the region under consideration. On the Pacific coast the range is from San Diego, California, northward, and the species is known from Chile, if the synonymizing of the South American form with the northern is correct.

Heptranchias Rafinesque, 1810.

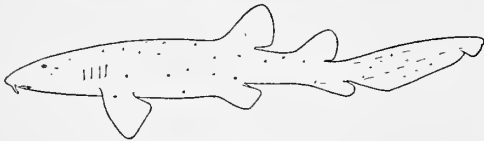
The seven-gilled sharks also have representatives both north and south of the region from Cedros Island to northern Peru.

Family ORECTOLOBIDAE.

Ginglymostoma Muller & Henle, 1837.

Ginglymostoma cirratum (Gmelin).

Nurse Shark (Sand Shark; Gato).



Text-figure 2.

Range: In our province from the Gulf of California, south to Ecuador. (Mexico: Gulf of California, Mazatlan, Jalisco, Chamela Bay, Manzanillo; Costa Rica: Port Parker, Potrero Grande, Gulf of Nicoya; Panama: Bahia Honda, Panama Bay; Ecuador: St. Helene Bay.)

Field Characters: A sluggish, blunt-headed shark with very small eyes; mouth transverse and near the tip of the snout, furnished with a pair of barbels; two large dorsal fins placed far back, the first over the pelvis; the fourth and fifth gill-slits very close together. Olive brown; young covered with small black spots which usually disappear in the adult. (Illustration after Garman; 365 mm.)

No detailed comparison has been made at first hand between nurse sharks from the Atlantic and from the Pacific, and though probably there is specific differentiation, we can consider them at present as only a single species.

Size: Reaches a length of 10 feet.

Local Distribution: Feeding and usually living close to the bottom in shallow water near shore.

Abundance: Cannot be considered a rare shark wherever it is found.

Food: A 385 mm. shark taken from a tide pool in Costa Rica had eaten two carideans and five small fishes. One of the latter was a *Rupiscartes atlanticus* (85 mm.) and another an *Anchoviella* (43 mm.). An adult shark had eaten a six-inch fish.

Enemies: Man was the only enemy of this shark which came to our notice. A dozen nurse sharks, six to eight feet in length, were found on the beach at a camp devoted to drying shark fins, near the tip of Lower California, on May 1, 1936. Unlike the other three species found at this camp, the nurse sharks had their fins intact, these having evidently no commercial value.

Parasites: Two leeches, *Pontobdella muricata*, were taken from a nurse shark.

Breeding: The largest specimen (2,800 mm.) showed no signs of active breeding; the smallest (295 mm.) was taken in a tide pool at Bahia Honda, Panama, on March 19, 1938.

Study Material: We observed this shark seven times; three specimens were collected, the others were watched through helmet or water-glass. Mexico: Chamela Bay, 1, observed, ca. six feet, Nov. 10, 1937; Manzanillo Bay, 1 (26,093) 392 mm., Jan. 10, 1938, poisoned; Costa Rica: Port Parker, 1, ca. four feet, Jan. 13, 1938, observed; Potrero Grande, 1, ca. seven feet, Jan. 23, 1938, observed in 2 feet of water; Gulf of Nicoya, (26,170) 2,880 mm., Feb. 23, 1938, snagged through dorsal with hook from *Zaca*; Panama: Bahia Honda, 1, (26,206) 295 mm., March 19, 1938, poisoned in tidepool; Bahia Honda, 1, ca. 300 mm., March 19, 1938, specimen lost, from same pool as 26,206.

References: *Squalus cirratus*, Bonnaterre, Tabl. encyc. meth., Ichthy., 1788: 7 (original description).

Ginglymostoma cirratum, Jordan, D. S. & Gilbert, C. H., *Bull. U. S. Fish Comm.*, 2, 1882: 105 (Mazatlan, Mexico). Jordan, D. S. & Gilbert, C. H., *Proc. U. S. Nat. Mus.*, 5, 1883: 371 (First record from Pacific coast, 2 ten-inch specimens collected by Xantus, Colima, Mexico). Jordan, D. S. & Gilbert, C. H., *Proc. U. S. Nat. Mus.*, 5, 1883: 620 (Panama). Vaillant, L. L., *Bull. Soc. Philom., Paris*, (8) 6, 1894: (Gulf of California). Jordan, D. S., *Fishes of Sinaloa*, 1895: 381, (color, common name "Gata," 3 specimens, 2 to 6 feet). Jordan, D. S. & Evermann, B. W., *Fishes North and Middle America*, 1, 1896: 26 (short description). Boulenger, G. A., *Boll. Mus. Torino*, 13, 1898: 1 (Ecuador). Gilbert, C. H. & Starks, E. C., *Fishes Panama*

⁴ Garman, S., *Mem. Mus. Comp. Zool.*, 24, 1899: 41.

Bay, 1904: 5 (color, Panama). Garman, S., *Bull. Mus. Comp. Zool.*, 46, 1906: 229 (Panama). Regan, C. T., *Proc. Zool. Soc. London*, 1908: 350 (synonymy, description, Jalisco, Mexico). Garman, S., *The Plagiostomia*, 1913: 54, plate 7 (description, figures). Meek, S. E., & Hildebrand, S. F., *Marine Fishes of Panama*, 1, 1923: 29 (Panama, description).

Ginglymostoma fulvum, Jordan, D. S., *Proc. U. S. Nat. Mus.*, 8, 1886: 363 (listed as a doubtful species).

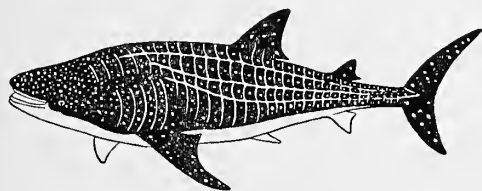
Family RHINEODONTIDAE.

Rhincodon Smith, 1849. (Usually considered as a misprint for *Rhineodon*.)

Rhineodon typus Smith.

Whale Shark.

(Plate 1, Figs. 1 & 2).



Text-figure 3.

Range: Warm waters of the Atlantic, Pacific and Indian Oceans. In the eastern tropical Pacific it is known from the following localities, Mexico: Gulf of California, Cape San Lucas, Acapulco; Panama: Panama Bay, Galápagos Islands; Peru: Callao.

Field Characters: A giant whale-like shark with spotted head and with the body covered with longitudinal and transverse pale bands forming a checker-board; each space in the checker-board with a pale yellowish spot. (Illustration after Norman, 1937.)

Size: Grows to 45 feet long, with possible records ranging up to 70 feet.

General Habits: Considering its size, this is a common fish in Gulf of California waters. Our observations on the species are summarized in "Zaca Venture," pages 162-170.

Study Materials: No specimens. Many observations and photographs were made of this species in the Gulf of California.

References: *Rhincodon typus*, Smith, A., *Zool. Journal*, London, 16, 1829: 443-444 (original description; type locality, Table Bay, Cape of Good Hope, South Africa).

Micristodus punctatus, Gill, T. N., *Proc. Acad. Nat. Sci., Phila.*, 17, 1829: 177. Gill, T. N., *Science*, 15, 1902: 824-826. Jordan, D. S. & Evermann, B. W., *Fishes North and Middle America*, 1, 1896: 52 (Quotes original description of teeth). Mowbray, L. L., Preliminary Report on the Taking of the Pacific Whale Shark during

the Scientific Cruise of the Yacht "Nourmahal" in the North Pacific, 1933, under the direction of Vincent Astor, Privately printed, July, 1933, No. 1, 2 pp. (Galápagos Islands).

Rhineodon typicus, Smith, R. W., *Illustrations Zool. South Africa*, 1849: Plate 26. Nation, W. S., "South Pacific Times," Callao, Peru, Jan. 24, 1878. (Callao, Peru). Chierchia, G., *Collezioni per Studi di Scienze Naturali Fatte nel Viaggio Intorno al Mondo della R. Corvetta "Vettor Pisani"* Anni 1882-83-84-85. Roma, 1885: 66-68 (Panama Bay). Grey, Z., *Santa Catalina Islander*, May 27, 1925: 10 (Cape San Lucas). Grey, Z., "Fishing Virgin Seas," *New York*, 1925: 204-216 (Cape San Lucas). Beebe, W., "The Arcturus Adventure," *New York*, 1926: 414 (Galápagos Islands). Gudger, E. W., *Science*, 65, 1927: 545 (Galápagos Islands). Gudger, E. W., *Science*, 65, 1927: 211-212 (Gulf of California). Gudger, E. W., *Nature*, 132, 1933: 569 (Galápagos Islands). Lonnberg, E., *Fauna och Flora Upsala*, 1933: 97-104 (Acapulco, Mexico). Gudger, E. W., *Proc. Zool. Soc. London*, 1934: 874-878 (Distribution in the eastern tropical Pacific). Gudger, E. W., *Natural History*, 36, 1935: 128-132 (Acapulco, Mexico). Gudger, E. W. & Smith, R. S., *Bull. N. Y. Zool. Soc.*, 68-71 (six specimens at Acapulco, Mexico, photographs). Beebe, W., *Bull. N. Y. Zool. Soc.*, 39, 1936: 241-242 (notes, photographs), (Gulf of California, Cape San Lucas). Gudger, E. W., *Nature*, 141, 1938: 516 (Panama). Gudger, E. W., *California Fish and Game*, 24, 1938: 420-421 (Lower California). Fowler, H. W., *Acad. Nat. Sci. Phila.*, Monograph 2, 1928: 248 (Galápagos Islands, check-list). Beebe, W., "Zaca Venture," *New York*, 1938: 162-170 (observations and harpooning, abundance, size, Gulf of California and Cape San Lucas).

Family ALOPIIDAE.

Alopias Rafinesque, 1810.

Alopias vulpinus (Bonnaterre).

The thresher-shark, although supposedly world-wide in distribution, is unrecorded from our area, but it has been found in considerable numbers in southern California and in Chile. Walford, in writing of southern California *Alopias vulpinus*, states: "It has been recorded on our coasts as far north as Coos Bay, Oregon, and is said to extend at least as far south as the Isthmus of Panama." This statement seems to be the only recorded reference to the species in coastal tropical eastern Pacific waters.

Alopecias barrae Philippi⁵ and *A. longimana* Philippi,⁶ both reported from Chile, are considered by Fowler⁷ as being the same as *Alopias vulpinus*.

⁵ Philippi, R. A., *Anales Univers. Chile*, 71, 1887: 553, pl. 5, fig. 2.

⁶ Philippi, R. A., *Anales Univers. Chile*, 109, 1901: 308.

⁷ Fowler, H. W., *Proc. 4th Pac. Sci. Congr., Java* 1929, *Biol. Pap.* 3, 1930: 488.

Whitley⁸ points out that the assumption that *Alopias vulpinus* has a world-wide distribution may not be correct. A number of new forms of *Alopias* have been described, and the eastern tropical Pacific form may very well represent another species.

Family ISURIDAE.

Key to genera mentioned in this paper.

- 1a. Teeth slender and sharp, with entire edges.
 1b. Teeth compressed and triangular, with serrated edges. *Isurus*
 *Carcharodon*

Isurus Rafinesque, 1810.

- 1a. Teeth with a basal cusp on each side. *nasus*
 1b. Teeth without basal cusps, long, flexible and acute. *glaucaus*

Isurus nasus (Bonnaterre) and *Isurus glaucus* (Müller & Henle).

The genus *Isurus* and the species mentioned above are unreported from our province, although they are present north and south of the area if the Chilean *Lamna hudsoni*⁹ is the same as *Isurus glaucus* as Fowler states,¹⁰ and if *Lamna philippi* Perez¹¹ is the same as *Isurus nasus*, as Fowler mentions in the same publication.

We have the jaws of an *Isurus* obtained from a native in the Gulf of Dulce, Costa Rica. There is no definite locality record for this jaw, and although it was probably taken from somewhere within our region, we have no positive assurance that this was so.

This specimen would be referred to *glaucus* in the key. There are 13 teeth on each side in each jaw, the teeth becoming progressively smaller from front to back. The teeth are smooth and there is no indication of cusps. The longest teeth measure 31 mm. from base to tip. In the upper jaw the third tooth is considerably smaller than the following teeth, being approximately equal in size to the eighth. The space between the third and fourth teeth in the upper jaw is wider than the spaces between other teeth.

Carcharodon Müller & Henle, 1838.

Carcharodon carcharias (Linnaeus).

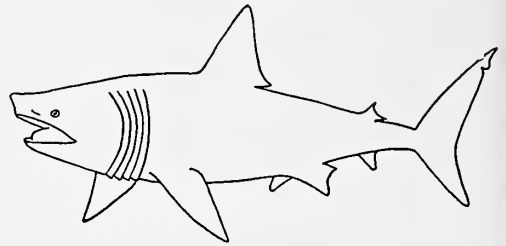
There seems to be no authentic record of the great white shark in our region, although from the distribution of the species one would expect to find it. It is recorded from southern California and from Chile.

Family CETORHINIDAE.

Cetorhinus Blainville, 1816.

Cetorhinus maximus (Gunner).

Basking Shark.



Text-figure 4.

Range: Arctic, Antarctic and temperate seas; in the eastern tropical Pacific it is known from Ecuador and Peru and from somewhere near the Galápagos Islands. On the northern limit of the area under discussion it is known from southern California, and there is a questioned record from near Cape San Lucas.

Field Characters: A very large shark with long gill-slits extending from the back and almost meeting under the throat. Caudal fin lunate, with keels on each side near the base. Back leaden gray, lower sides white. Often found drifting at the surface. (Illustration after Norman, 1937.)

Size: Grows to 45 feet.

Study Material: None.

References: *Squalus maximus*, Gunner, J. E., *Trondjhem sels.*, 3, 1765: 33, tab. 5 (original description, coast of Norway).

Cetorhinus, Stevenson, C. H., *Rep't. U. S. Fish Comm.* 28, 1902 (1904): 227-228 (Peru and Ecuador, use for oil). Gudger, E. W., *Science*, 42, 1915: 653-656 (Occurrence in the southern hemisphere).

Basking shark, Grey, Z., "Tales of Fishing in Virgin Seas," New York, 1925: 185 (Questionable sight record, Cape San Lucas. "I saw the dark leathery fin of a basking shark stick up out of the water. It was immense. But before we could get near enough for a picture it sank").

Cetorhinus maximus, Gudger, E. W., *Science*, 65, 1927: 545 (locality "not far from the Galápagos"). Fowler, H. W., *Proc. 4th Pac. Sci. Congr.*, Java 1929 (1930): 489 (range; includes California, Ecuador, Peru). Gudger, *Proc. Zool. Soc. London*, 1934 (1935): 877 (Contains the following statement ". . . and not *Cetorhinus*, which latter shark is, however, found all along the western coast of South America, and even in the vicinity of the Galápagos Archipelago.")

Discussion: As Norman suggests (*Discovery Reports*, 16, 1937: 7) the southern basking shark, as represented by Falkland Island and southern

⁸ Whitley, G. P., *Rec. Austr. Mus.*, 20 (1), 1937: 5.

⁹ Philippi, R. A., *Anales Univers. Chile*, 71, 1887: 551.

¹⁰ Fowler, H. W., *Proc. 4th Pac. Sci. Congr.*, Java 1929, Biol. Pap. 3, 1930: 488.

¹¹ Perez, C. C., see Philippi, R. A., *Anales Univers. Chile*, 71, 1887: 549.

South American specimens, may prove to be distinct from the northern species. The specimens from Peru, Ecuador and the Galápagos Islands may represent a northward projection of the range of this southern race or species of basking shark.

The record of basking shark near Cape San Lucas, made by Zane Grey in "Tales of Fishing in Virgin Seas," page 185, must be questioned until further records of this shark are secured in Gulf of California waters. The record was merely the sight of a dorsal fin which disappeared before Grey could approach near enough to secure a photograph.

Family SCYLLIORHINIDAE.¹²

Key to genera and species of the tropical eastern Pacific.¹³

- 1a. Labial folds absent or rudimentary; belly capable of inflation. (Color grayish-brown, tinged with yellowish above and below; back with black cross-bars; upper parts with large round black spots. *Cephaloscyllium uter*)
- 1b. Labial folds present; belly not inflatable.
 - 2a. First dorsal fin originating behind the origin of the pelves; base of the second dorsal fin shorter and wholly above that of the anal fin, the latter overlapping it before and behind; belly pale. *Pristiurus xaniurus*
 - 2b. First dorsal fin originating well in front of the pelves; second dorsal fin about equal to the anal in size, and terminating slightly behind it; belly same color as rest of the body. *Cephalurus cephalus*

¹² The genera in this family are not easy to differentiate and it is possible that many of them ought to be merged or at least recognized as subgenera. We have here followed Garman, 1913, except for the use of *Scylliorhinus* in place of *Catulus*.

Halaelurus chilensis (Guichenot) of Chilean and southern South American waters, approaches the borders of the region under consideration. It has been recorded from Mollendo, Peru, by Evermann, B. W. & Radcliffe. L. (*Bull. U. S. Nat. Mus.*, 95, 1917: 3).

¹³ *Apristurus brunneus* (Gilbert). The range of this species has been noted as including the Gulf of California. However, this is not true and the species is known, as far as the literature is concerned, only from north of the United States boundary. The history of the false Gulf of California record seems to be as follows:

In the original description of *Catulus brunneus* (*Proc. U. S. Nat. Mus.*, 14, 1891 (1892): 542), which is included in a paper entitled "Descriptions of thirty-four new species of fishes collected in 1888 and 1889, principally among the Santa Barbara Islands and the Gulf of California," no mention is made of the type locality of the species. Jordan & Evermann, in "Fishes of North and Middle America," Vol. 1, page 24, supplied the deficiency by stating "Gulf of California," and this notation has been copied in a number of papers. Unfortunately, this selection of a type locality is not in accord with the known distribution of *brunneus* and, in addition, a checking of the type, No. 51,708, U. S. National Museum, reveals that it was taken at *Albatross* station No. 2396, 32° 49' N. Lat., 117° 28' 30" W. Long., in 359 fathoms, on February 4, 1889. This locality is about 10 miles west of Point La Jolla, California, quite within the generally known range of the species, and a long distance from the Gulf of California.

Apristurus brunneus may thus be removed from consideration as a Gulf of California species, and the type locality should be changed in the literature to coincide with the notes given above.

Cephaloscyllium Gill, 1861.

Cephaloscyllium uter (Jordan & Gilbert).

Swell Shark.



Text-figure 5.

Range: Monterey Bay to northern Lower California, with a single record at Acapulco, Mexico.

Field Characters: Small, blunt-headed sharks with first dorsal fin far back on the body, over the pectoral fins; teeth small, tricuspid, in about four series. Grayish-brown with bands and spots of black, sometimes with white spots on the body. Belly capable of great inflation. (Illustration after Jordan & Evermann, 1900: 790 mm.).

Size: Grows to about three feet.

Study Material: None.

References: *Catulus uter*, Jordan, D. S., & Gilbert, C. H., in Jordan, D. S., & Evermann, B. W., "Fishes of North and Middle America," 1, 1896: 25 (new name and description, questions relationship to Chilean *ventriosus*).

Scylliorhinus ventriosus, Garman, S., *Mem. Mus. Comp. Zool.*, 24, 1899: 26 (" . . . *S. ventriosus* Garman, from Acapulco and northward . . .").

Discussion: All of the records of this species with the exception of one are from the region from Monterey, California, to Ensenada, Mexico. The exception is the record of Garman, listing the species from Acapulco, Mexico.

Garman, in the Acapulco record, synonymized the northern form *uter*, with the Chilean *ventriosus* which he had described in 1880. The similarity and dissimilarity of the northern and southern forms had been recognized by Jordan & Gilbert when the name *uter* was given to the California specimens. Considering the lack of records from the warm waters south of Acapulco, we retain the California form as a species distinct from the South American one.

Pristiurus Müller & Henle, 1838.

Pristiurus xaniurus (Gilbert).

File-tail Shark.



Text-figure 6.

Range: Coast of southern and Lower California, south to San Roque Bay, in 184 to 684 fathoms.

Field Characters: Small sharks with two dorsal fins placed far back on the body, the first dorsal above the ventrals; anal fin present; upper edge of caudal in adult with a broad band of enlarged scales; labial fold of lower jaw slightly shorter than the fold of the upper jaw. Dark slaty brown, usually uniform above, sometimes with small whitish spots, the fins often edged with paler; belly pale. (Illustration after Garman, 1913: 552 mm.)

Size: Grows to about two feet.

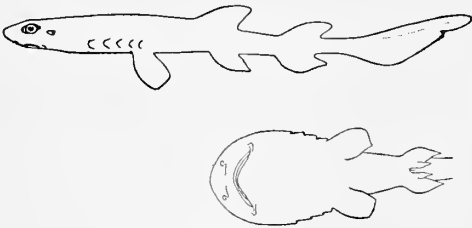
Study Material: None.

References: *Catulus xaniurus*, Gilbert, C. H., *Proc. U. S. Nat. Mus.*, 14, 1891 (1892): 540 (original description, abundance; type locality, Southern and Lower California, in 184 to 684 fathoms). Gilbert, C. H., *Rep't. U. S. Fish Comm.*, 1893 (1895): 461 (off Central California in 200 to 456 fathoms; spines and spinelets, young, claspers). Jordan, D. S. & Evermann, B. W., *Fishes of North and Middle America*, 1, 1896: 24 (description). Townsend, C. H., & Nichols, J. T., *Bull. Amer. Mus. Nat. Hist.*, 52, 1925: 5 (18 specimens from 27° 07' N., 114° 33' W., off San Roque Bay, Pacific coast of Lower California, in 284 fathoms).

Parmaturus xaniurus, Walford, L. A., *Div. Fish and Game California, Fish Bull.*, 45, 1935: 27 (short description, distribution, figure). Garman, S., *The Plagiostomia*, 1913: 90, Plate 9, figs. 1-5 (description, figure).

Cephalurus Bigelow & Schroeder, 1941.

Cephalurus cephalus (Gilbert).



Text-figure 7.

Range: Gulf of California; 85 to 100 miles N. W. of Cape San Lucas, Lower California, and near Clarion Island, in 85 to 460 fathoms.

Field Characters: Very small, rather broad-headed sharks with wide crescentic mouth; second dorsal fin about equal to anal in size, with its posterior base termination behind that of the anal; brown, the belly same color as the rest of the body. (Illustration after Bigelow & Schroeder, 1941.)

Size: Grows to about 10 inches.

Study Material: 1 specimen. Mexico, off the south-western Coast of California, No. 12,831, *Amer. Mus. Nat. Hist.*, length 206 mm.

References: *Catulus cephalus*, Gilbert, C. H., *Proc. U. S. Nat. Mus.*, 14, 1891 (1892): 541 (original description, Gulf of California at 362 fathoms, and near Clarion Island at 460 fathoms). Garman, S., *The Plagiostomia*, 1913: 78 (short description; comment on inadequacy of the original description; placed provisionally in *Catulus*). Townsend, C. H., & Nichols, J. T., *Bull. Amer. Mus. Nat. Hist.*, 52, 1925: 6 (specimens from 85 to 100 miles northwest of Cape San Lucas, in 389 to 405 fathoms).

Family TRIAKIDAE.

Key to tropical eastern Pacific genera.

- 1a. Spiracles present; no caudal pit.....*Triakis*
- 1b. Spiracles absent; caudal pit present.*Triaenodon*

Triakis Müller & Henle, 1838.

Key to tropical eastern Pacific species.¹⁴

- 1a. Grayish with cross bands and large alternating spots of brown; median cusp of teeth acuminate, lateral cusps short.....*semifasciata*
- 1b. Slaty brown, with scattered small spots of black; median cusps of teeth short, broad-based, lateral cusps short.....*maculatus*

Triakis semifasciatum Girard.



Text-figure 8.

Range: Cape Mendocino, California, to Magdalena Bay, Lower California. (Mexico: Cedros Island, Port San Bartholomae, Turtle Bay, Ballenas Bay and Magdalena Bay.)

Field Characters: An easily recognizable shark: gray with well-defined cross bands of black on the upper parts, interspaced with round black dots along the sides.

Size: Grows to about 3 feet in males, females over five feet.

Study Material: We have no material. At Clarion Island in the Revillagigedo group, a specimen supposedly of this species was caught and lost on a feather-fly. The shark was about four feet long.

References: *Triakis semifasciatum*, Girard, C. F., *Proc. Acad. Nat. Sci. Phila.*, 7, 1854: 196 (original description; type locality, Presidio de San Francisco). Lockington, W. N., *Proc. Acad. Nat. Sci. Phila.*, 1881 (1882): (Magdalena Bay). Fowler, H. W., *Proc. Acad. Nat. Sci. Phila.*, 60, 1908: 59 (Use of *felis* in place of *semifasciatum*). Osburn, R. C., & Nichols, J. T., *Bull. Amer.*

¹⁴ From Garman, S, 1913: 165.

Mus. Nat. Hist., 35, 1916: 141 (3 specimens in seines, Cedros Island, Port San Bartholome and Ballenas Bay, Lower California). Wales, J. H., *Copeia*, 1932: 163 (Ensenada and Turtle Bay, Lower California; many seined at latter locality). Walford, L. A., *Div. Fish and Game California, Fish Bull.*, 45, 1935: 32 (Short description, range, etc., figure). Barnhart, P. S., *Mar. Fishes South. California*, 1936; 9, fig. 14 (short description and color; figure).

***Triakis maculata* Kner & Steindachner.**

Range: Recorded by Fowler from California, Mexico, Peru and Chile.

Field Characters: Small sharks; slaty brown with numerous irregular scattered spots of black on the back and flanks. Teeth small, numerous, more than two rows functioning, each tooth with the central cusp short, broad at base and directed obliquely outward; the lateral denticles of each tooth are mere rudiments separated from the principal cusp by a shallow notch.

Size: Grows to about two feet.

Study Material: None.

References: *Triakis maculatus*, Kner, R., & Steindachner, F., *Sitzb. Akad. Wiss. Wien*, 54, 1867: 391 (original description, "Sudsee," Listed as "*Triakis scyllium* Dum., vel *maculata*, n. sp.). Steindachner, F., *Sitz. Akad. Wiss. Wien*, 60, 1870: 315 (Mazatlan, Mexico). Garman, S., *The Plagiostomia*, 1913: 167 (Redescription of the species from Callao, Peru, specimens). Fowler, H. W., *Proc. 4th Pac. Sci. Congr.*, Java 1929, *Biol. Pap.* 3; 1930: 490 (Lists following range: California, Mexico, Peru and Chile).

Discussion: This species was described by Kner & Steindachner from a specimen taken from the indefinite locality "Sudsee." However, the other species of fish listed in the same paper are from Chile and Peru, so that it is not unlikely that the types came from the west coast of South America. In 1870 Steindachner listed a specimen from Mazatlan, Mexico, and in 1913 Garman redescribed the species from specimens taken at Callao, Peru. Fowler in 1930 listed the range as we have recorded it. We have been unable to find the Californian and Chilean references upon which the range is based.

***Triaenodon* Müller & Henle, 1837.**

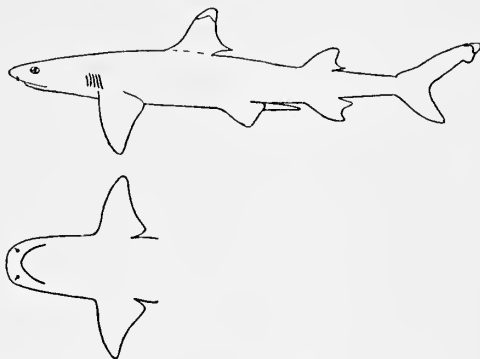
***Triaenodon obesus* (Ruppell).**

(Plate II, Fig. 1).

Range: Red Sea, Indian Ocean, Oceania including Hawaii, Cocos Island and Panama. (In the eastern tropical Pacific three specimens are known, two from Cocos Island and one from Bahia Honda, Panama. The Panama specimen here recorded is the first reported occurrence of the species on the American continent.)

Field Characters: A blunt-headed shark with mouth close to and paralleling the outer border

of the head; nostrils with a conspicuous triangular flap; nictitating membrane present; first dorsal fin nearer ventrals than pectorals; teeth with a long median cusp and with a smaller cusp, rarely two, at the base on each side; tips of the dorsal fins and the upper caudal lobe white. (Illustration after Fowler, 1928: 645 mm.)



Text-figure 9.

Description: The single specimen secured by us agrees with current descriptions.¹⁵ For comparative purposes we append the following account of this 1,175 mm. (46¼ inches) fish. Proportions are stated in percentages of the length to the tip of the last caudal vertebrae (1,125 mm.).

Head broad, depressed, the upper surface quite flat; snout broadly rounded, the mouth close to and paralleling the outer border of the head but slightly nearer the sides of the head laterally than anteriorly; preoral length 3.6%, width of mouth 8.5; symphysis of lower jaw to line joining the angles of the jaw 4.7; mouth strongly arched with a small crease on the upper lip on each side and with a deep pit at the gape on each side in the lower jaw. Nostrils to snout 3.7; internarial space 4.6; nostrils with a large conspicuous triangular flap on their inner halves. Eye a broad horizontal oval with a large nictitating membrane, diameter 1.85; distance from snout to eye 6.9; distance from eye to mouth 2.7. Snout to first gill-opening 18, snout to fifth gill-opening 22; height of first gill-opening 2.65, height of fifth gill-opening 3.1; last gill-slit over the base of the pectoral fin. Snout to first dorsal fin 38, the fin rather sharp superiorly and with a sharp-pointed posterior lobe; first dorsal fin much closer to pelvics than to the pectorals; base of first dorsal 8.9, anterior edge 12.2, vertical height of fin from body 9.2, base to tip of lower lobe 4.4. Interdorsal space 17.8. Snout to

¹⁵ The eastern Pacific records of the genus (Cocos Island, Hawaii) have been considered up to the present, as referable to *obesus*. Whitley, however (*Australian Zoologist*, 9 (3) 1939: 237), suggests that the Hawaiian form as represented by Fowler's Laysan Island example which the latter called *obesus*, is an "ally" of *obesus*.

As mentioned above our specimen agrees so closely with the current descriptions of *obesus* that we see no reason for using another name.

second dorsal fin 64; base of second dorsal 6.1, anterior edge 8.5, vertical height 6, base to tip of lower lobe 3.8, origin of fin very slightly ahead of the anal. Anal fin from snout 65.5, base 5, anterior edge 9.1, base to tip of posterior lobe 3.55. Base of second dorsal to upper caudal pit 8.35; base of anal to inferior caudal pit 8.35. Upper caudal pit to tip of caudal 24.8; inferior caudal pit to tip of lower caudal lobe 12.7; tip of caudal to notch of terminal lobe 6.75. Base of pectoral from snout 24.6, the fin large and low, its tip somewhat pointed, anterior edge of fin 14.6, inner edge 5, base of pectoral 5. Pelvic fins from snout 50, the fin truncate posteriorly, base of fin 6.1, anterior edge 7.3, inner edge of fin from the inner posterior tip to the separation of the fins anteriorly 6.5.

Teeth in both jaws tricuspid (rarely with five cusps), the median cusps much larger than the lateral ones, in about 45 rows in each jaw (the rear teeth difficult to count as the jaws were not dissected and the teeth extend far back into the mouth), those in the upper jaw erect anteriorly, becoming oblique and backwardly inclined on the sides posteriorly. Denticles from the upper side beneath the first dorsal fin are 5 to 7 keeled, the outer keels when 7 are present, very small, the denticles closely packed together.

Color: In life dark gray above, shading into dead white below, the tips of the second dorsal fin and the upper lobe of the caudal fin dead white. Irregularly scattered dark spots on the sides and tail, all smaller than the eye. Iris pale green with faint blackish angular lines.

Snodgrass & Heller state the color of their Cocos Island fish as follows: "dark uniform slate above, below livid yellowish slate; tip of 1st dorsal and of upper lobe of the caudal creamy white." Herre gives the color of his specimen from the same locality preserved in alcohol as: "more or less brownish or rusty brown above, paler to whitish beneath; the tips of the dorsals and upper caudal lobe are milky white, the margins of the other fins dark or blackish."

Size: Grows to at least 5 feet in our region.

Local Distribution: Our single specimen was speared close inshore at night.

Abundance: An uncommon species, represented by three records in the eastern Pacific American waters.

Food: The stomach of our fish contained a 205 mm. snapper-like fish.

Study Material: 1 specimen. Panama: Bahia Honda, 1, female (26186) 1,175 mm., Mar. 15, 1938, speared.

References: *Carcharias obesus* Ruppell, W. P. E. S., Neue Wirbelthiere zu der Fauna von Abyssinien gehörig, 1835: 64, Pl. 18, fig. 2 (original description, figure; type locality, Red Sea).

Triænodon obesus, Snodgrass, R. E., & Heller, E., *Proc. Wash. Acad. Sci.*, 6, 1905: 344 (range, description, color; Cocos Island); Fowler, H. W., *Proc. 4th Pac. Sci. Congr.*, Java, 1929, 3 (1930):

489 (Check list, range); Herre, A. W., *Field Mus. Nat. Hist., Zool. Ser.*, 21, 1936: 24 (short description, color, range; Cocos Island); Fowler, H. W., *Acad. Nat. Sci. Phila., Monograph* 2, 1938: 249 (check-list, Cocos Island).

Discussion: Whitley has recently pointed out that the genus *Triænodon* was mentioned earlier than the usually accepted first reference of Müller & Henle (*Syst. Besch. der Plagiostomen*, 1838-1841: 55). The references referred to are as follows: Müller & Henle, *Ber. Verh. kon. Preuss. Akad. Wiss. Berlin*, 2, 1837: 113, and *Mag. Nat. Hist.* (ed. Charlesworth) 2, 1838: 38.

In the last two references cited above there is no mention of a genotype. In the first reference, two species are recognized under *Triænodon*, *obesus* and *smithii*. As Müller & Henle state (footnote p. 56, of last-mentioned reference), that *smithii* belonged to the genus *Leptocarias*, it is obvious that *obesus* must be the genotype.

In our specimen of *Triænodon obesus*, the nictitating membrane is complete and not a fold, as is indicated in White's "Key to Galea" (*Bull. Amer. Mus. Nat. Hist.*, 74, 1937: 121) in alternative (55).

Family MUSTELIDÆ.

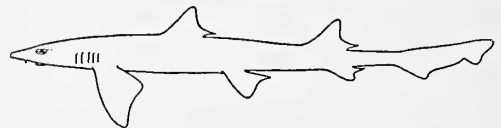
Mustelus Linck, 1790.¹⁶

Key to species of the tropical eastern Pacific.

- 1a. Lower lobe of the caudal fin pointed, arcuate.
lunulatus
- 1b. Lower lobe of caudal fin rounded.
 - 2a. Midpoint of base of first dorsal fin much closer to origin of ventral fins than to axil of the pectorals.....*californicus*
 - 2b. Midpoint of base of first dorsal fin as close to axil of pectoral fins as to the ventrals or closer.....*dorsalis*

Mustelus californicus Gill.

Gray Smooth Hound.



Text-figure 10.

Range: Cape Mendocino, California, southward into the Gulf of California (Mexico: "Lower California," Magdalena Bay, Cape San Lucas, Rio Colorado, Guaymas).

Field Characters: Small sharks with teeth in flattened pavement-like rows; preoral length about equal to or a little less than the width of the mouth; lower lobe of caudal fin ending obtuse-

¹⁶ We have made no attempt to consider the species of the genus recorded from Peru and southward. Some of these may belong to other genera; they are *mento* (*edulis*), *abbotti* and *nigromaculatus*. See Bigelow & Schroeder, *Proc. Boston Soc. Nat. Hist.*, 41 (8) 1940: 417-438), for data on these forms.

ly; center of base of first dorsal fin nearer root of ventrals than pectorals. Dark lead gray, white below. (Illustration from specimen No. 443, Mus. Comp. Zool.; 615 mm.).

Size: Grows to about 3½ feet.

Study Material: 3 specimens. Mexico: Cape San Lucas, 3 (24815, 24821, 24822) female and two embryos about to be born, March 30, 1936, hand line (only embryos saved).

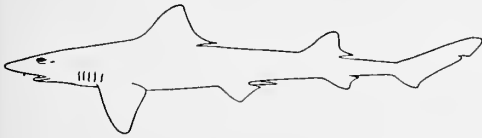
References: *Mustelus californicus*, Gill, T. N., *Proc. Acad. Nat. Sci. Phila.*, 16, 1864: 148 (original description, type locality, San Francisco, California). Lockington, W. N., *Proc. Acad. Nat. Sci. Phila.*, 1881: 114 (Lower California). Starks, E. C., *Copeia*, 46, 1917: 61-63 (comparison with *M. henlei* and *M. lunulatus*; Mexico: Ensenada and Magdalena Bay). Springer, S., *Proc. U. S. Nat. Mus.*, 86, 1939: 468 (in key to genus).

Galeorhinus californicus, Breder, C. M., Jr., *Bull. Bingham Oceano. Coll.*, 2 (1), 1926: 3 (Rio Colorado, Lower California).

Galeus dorsalis, Evermann, B. W., & Jenkins, O. P., *Proc. U. S. Nat. Mus.*, 14, 1891: 129 (Guaymas, Mexico; embryo; see Gilbert & Starks, Fishes of Panama Bay, p. 7).

Mustelus dorsalis Gill.

Tollo.



Text-figure 11.

Range: Gulf of California, southward to Colombia and ? Peru. (Mexico: Gulf of California; Costa Rica: Uvita Bay; Panama: Panama; Peru: Callao.)

Field Characters: Small sharks with teeth in flattened, pavement-like rows; preoral length about equal to width of mouth; first dorsal fin with center of its base equidistant from base of pectoral and ventral fins; lower lobe of caudal fin not prominent, ending obtusely; uniform grayish above, whitish below, no conspicuous color markings. (Illustration from specimen No. 26,176: 488 mm.)

Size: Grows to about three feet.

Study Material: 1 specimen. Costa Rica: Uvita Bay, male (26176) 480 mm., March 2, 1938, taken on hand line.

References: *Mustelus dorsalis*, Gill, T. N., *Proc. Acad. Nat. Sci. Phila.*, 1864: 149 (original description; Panama, type No. 8068, U. S. Nat. Mus.). Günther, A., *Trans. Zool. Soc. London*, 6 (7), 1868: 396 (check list), 490 (copied description). Günther, A., *Cat. Fishes Brit. Mus.*, 8, 1870: 388 (note). Jordan, D. S. & Gilbert, C. H.,

Bull. U. S. Fish Comm., 2, 1882: 109 (name only, Panama). Jordan, D. S., & Gilbert, C. H., *Proc. U. S. Nat. Mus.*, 5, 1882 (1883): 109 (Key differentiating this species from *lunulatus* and *canis*). Jordan, D. S., & Gilbert, C. H., *Proc. U. S. Nat. Mus.*, 5, 1882 (1883): 373 (List of Dow's specimens, type from Panama). Pellegrin, J., *Bull. Mus. Hist. Nat., Paris*, 7, 1901: 161 (Gulf of California). ? Evermann, B. W., & Radcliffe, L., *U. S. Nat. Mus., Bull.* 95, 1917: 7, plate 1, fig. 3, plate 2, fig. 1 (measurements, description, figures). Nichols, J. T. & Murphy, R. C., *Bull. Amer. Mus. Nat. Hist.*, 46, 1922: 504 (Callao, Peru). Springer, S., *Proc. U. S. Nat. Mus.*, 86, 1939: 467 (in key).

Galeus dorsalis, Jordan, D. S., *Proc. U. S. Nat. Mus.*, 8, 1885 (1886): 363 (check-list, Panama). Jordan, D. S., & Bollman, C. H., *Proc. U. S. Nat. Mus.*, 12, 1889 (1890): 179 (name only). Gilbert, C. H., *Proc. U. S. Nat. Mus.*, 13, 1890 (1891): 449 (Panama). Jordan, D. S., & Evermann, B. W., *Fishes North and Middle America*, 1, 1896: 30 (description, range, color). Gilbert, C. H., & Starks, E. C., *Fishes of Panama Bay*, 1904: 7, Plate 1, fig. 2 (comments on description, measurements, figure of head). Osburn, R. C. & Nichols, J. T., *Bull. Amer. Mus. Nat. Hist.*, 35, 1916: 141 (Tiburón Island, Gulf of California; three-foot female with six unborn ten-inch young).

Galeorhinus dorsalis, Garman, S., *The Plagiostomia*, 1913: 178 (synonymy, description, color). Meek, S. E. & Hildebrand, S. F., *Marine Fishes of Panama*, 1, 1923: 32 (short synonymy, note on embryos, description; Panama market).

Mustelus lunulatus Jordan & Gilbert.



Text-figure 12.

Range: Southern California to Colombia. (Mexico: Santa Inez Bay, Concepcion Bay, Guaymas, Mazatlan; Costa Rica: Port Parker; Panama: Panama Bay; Colombia: Gorgona Island.)

Field Characters: Small sharks with teeth in flattened pavement-like rows; preoral length greater than width of mouth; center of base of first dorsal closer to base of pectoral fins than to pelvis; lower lobe of caudal fin prominent, ending in a point. Uniform grayish above, pale below. (Illustration after Kumada & Hiyama, 1937: 472 mm.)

Size: Grows to 5 feet 8 inches.

Study Materials: 6 specimens. Mexico: Santa Inez Bay, Lower California, 2, April 13, 1936 (not saved); Santa Inez Bay, 1, 4 feet long; April 23, 1936 (not saved); Concepcion Bay, 1 (24994), April 13, 1936. Costa Rica: Port

Parker, 1 (26114), 700 mm., Jan. 16, 1938, captured on hook, teeth saved; Colombia: Gorgona Island, 1 (26211), 890 mm., March 27, 1938.

References: *Mustelus lunulatus*, Jordan, D. S. & Gilbert, C. H., *Proc. U. S. Nat. Mus.*, 5, 1882: 108 (original description; type locality: Mazatlan, Mexico; type No. 29211, U. S. Nat. Mus.). Jordan, D. S. & Gilbert, C. H., *Bull. U. S. Fish Comm.*, 2, 1882 (1883): 105 (check-list, Mazatlan, Mexico). Jordan, D. S. & Evermann, B. W., *Fishes North and Middle America*, 1, 1896: 28 (description). Jordan, D. S. & Evermann, B. W., *Fishes North and Middle America*, 3, 1898: 2745 (in key to west coast *Mustelus* and *Galeus*). Jordan, D. S. & McGregor, R. C., *Rep. Comm. Fish.* for 1898 (1899): 274 (Ensenada, Lower California, short description). Gilbert, C. H. & Starks, E. C., *Fishes of Panama Bay*, 1904: 5, Plate 1, fig. 1 (comparison with northern specimens, proportions, measurements, etc., figure), 207 (check-list, range). Starks, E. C., *Copeia*, 46, 1917: 63 (comparison with *Mustelus henlei* and *Mustelus californicus*). Norris, H. W., *Copeia*, 114, 1923: 1 (California, size, abundance, young). Kumada, T. & Hiyama, Y., *Marine Fishes Pacific Coast of Mexico*, 1937: 16, Plate 47 (Mexico; figure). Springer, S., *Proc. U. S. Nat. Mus.*, 86, 1939: 464 (comparison with *norrissi*, etc.), 467 (in key to *Mustelus*).

Galeus lunulatus, Jordan, D. S., *Proc. U. S. Nat. Mus.*, 8, 1885 (1886): 363 (check-list; name only). Evermann, B. W. & Jenkins, O. P., *Proc. U. S. Nat. Mus.*, 14, 1891 (1892): 128 (Guaymas, Mexico). Jordan, D. S., *Fishes of Sinaloa*, 1895: 382 (Mazatlan, abundance).

Galeorhinus lunulatus, Garman, S., *The Plagiostomia*, 1913: 174 (description, color, range). Meek, S. E. & Hildebrand, S. F., *Marine Fishes of Panama*, 1, 1923: 33 (short synonymy, description, comparison with *dorsalis*; range; Panama).

Cynias lunulatus, Starks, E. C. & Morris, E. L., *Univ. Cal. Publ. Zool.*, 3 (11), 1907: 163, 164 (comparison with *M. californicus*).

Family GALEORHINIDAE.

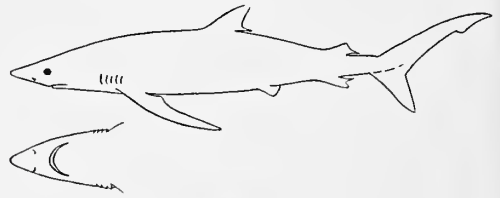
Key to genera of the tropical eastern Pacific.

- 1a. Spiracles absent.
 - 2a. Lower labial folds wanting or rudimentary.
 - 3a. First dorsal fin inserted posteriorly, the mid-point of its base nearer ventral than pectoral fins. *Prionace*
 - 3b. First dorsal fin inserted anteriorly, the mid-point of its base nearer pectoral than ventral fins.
 - 4a. Second dorsal fin almost as large in area as the first; teeth of both jaws smooth, narrowly triangular, with wide basal shoulders, the shoulders extending on each side of the central triangular portion. *Aprionodon*
 - 4b. Second dorsal fin very much smaller than the first dorsal; teeth of at least the upper jaw serrated, more or less triangular. *Eulamia*

- 2b. Labial folds well developed, present on both jaws; teeth not serrate. *Scoliodon*
- 1b. Spiracles present, small, situated behind the eye.
 - 5a. Teeth large, alike in both jaws, deeply notched on the outer edge and convex on the inner, heavily serrated; body in small and medium sized fish usually with irregular dark spots on the sides which often coalesce to form bars; these spots and bars tend to disappear with age. . . . *Galeocerdo*
 - 5b. Teeth not deeply notched, curved on both sides; color and pattern not as above
Galeorhinus

Prionace Cantor, 1849.

Prionace glauca (Linnaeus).



Text-figure 13.

Range: Tropical seas throughout the world; on the Pacific coast of America from Puget Sound southward to the Gulf of California; on the southern border of the tropical eastern Pacific it is recorded from Chile. (Mexico: Carmen Island, Gulf of California.)

Field Characters: Large, elongate sharks with short head and long tapering snout; first dorsal fin closer to pelvic fins than to pectorals; upper teeth triangular, convex externally, concave internally, all strongly serrated. Color above rich deep blue. (Illustration after Garman, 1913.)

Size: Grows to 15 to 20 feet.

Study Material: None.

References: *Galeus glaucus*, Linnaeus, *Systema Naturae*, 10th Ed., 1, 1758: 235 (original description).

Prionace glauca, Osburn, R. C., & Nichols, J. T., *Bull. Amer. Mus. Nat. Hist.*, 35, 1916: 141 (young specimen, hand-line, Carmen Island, Gulf of California).

Discussion: With the exception of the one Gulf of California specimen, records of this species are conspicuous by their absence in our region. The species is recorded north and south of the tropical eastern Pacific, both along the United States coast and in Chile.

Fowler has synonymized the Chilean *Carcharias pugae* Perez, *C. gracilis* Philippi and *C. aethiops* Philippi with this species. In addition to these Chilean records there are a number of others under the name of *glaucus*.

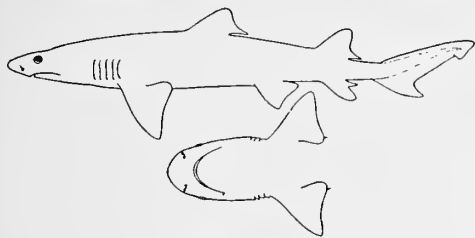
Whitley¹⁷ uses the name *Carcharhinus* in place of *Prionace* for the blue sharks. The former

¹⁷ Whitley, *Fishes of Australia*, Part 1, The Sharks, 1940: 107.

name has been hurled about to such a degree that we prefer retaining *Prionace* for the present for this genus.

Aprionodon Gill, 1861.

Aprionodon fronto (Jordan & Gilbert).



Text-figure 14.

Range: Mexico, Costa Rica. (Mexico: Guaymas, Mazatlan; Costa Rica: Port Parker. Our Port Parker specimen extends the range of this species some 1,500 miles southeastward along the coast.)

Field Characters: A shark with the second dorsal fin almost as large as the first, its base $4/5$ th as long as that of the first, the fin larger than the anal and originating slightly further forward; pectoral fin broad, its breadth 70% of the length of the fin; teeth of both jaws narrowly triangular with wide basal shoulders, edges of teeth smooth. (Illustration from Specimen No. 26,116: 704 mm.)

Description: The proportions, expressed in percentages of the total length, of the specimen obtained by the *Zaca*, are as follows: Specimen No. 22,116, 704 mm. total length. Length to caudal notch 76%; snout to origin of first dorsal fin 36.2; snout to origin of second dorsal fin 63; snout to origin of pelvic fins 50.5; snout to origin of anal fin 64.2; vertical of posterior pectoral base to origin of first dorsal fin 6.95; vertical of inner tip of pectoral fin to origin of first dorsal fin 2.8; First dorsal fin base 9.5, anterior edge 11.2, posterior edge 4.25, vertical height from body 6.4. Interdorsal space 19.2. Second dorsal fin base 6.95, anterior edge 8.7, posterior edge 3.7, vertical height of fin from body 6. Caudal fin length 22.5, tip to origin of terminal lobe 5.7, length lower lobe 11.2. Pectoral fin base 6.1, anterior edge 14.8, posterior edge 6.5, greatest breadth 10.7. Pelvic fin base 6.25, anterior edge 7.6, posterior edge 3.62. Anal fin base 5.35, anterior edge 7.7, posterior edge 3.05, vertical height from body 5. Snout to eye 7.95, eye diameter 1.8. Snout to mouth 5.26, mouth width 9.2, symphysis to line joining angles of the mouth 5.1. Snout to outer angle of nostrils 4.83, internarial space 5.55, nostril to mouth 2.7, length of nostril 1.63. Snout to 1st gill-slit 19.5, snout to 5th gill-slit 23.3. Height of 1st gill-slit 4.1, height of 5th gill-slit 4.1.

Teeth of both jaws narrowly triangular with

broad, shoulder-like basal portion and with no trace of serrations. Laterally the teeth tilt backwards, increasingly so posteriorly. The teeth farthest back, because of this tilting, have the posterior basal portion accentuated. The edges of the teeth are translucent and rather delicate and a ragged broken edge can be produced by the slightest effort.

Color: In life the upper surfaces are in general yellow-green; two broad dark bands begin at the nape and unite in back of the second dorsal fin. Below pale green, becoming almost white on the lower snout, chin and between the pectoral fins.

Size: The three known specimens of this species are small, 704, 723 and 915 mm. (27 to 36 inches).

Food: Our specimen contained the remains of an unidentifiable fish about 115 mm. long.

Local Distribution: Seined close inshore in daylight over a sandy beach.

Study Material: 1 specimen. Costa Rica: Port Parker, 1 female (26,116) 704 mm., Jan. 18, 1938, seined.

References: *Carcharias fronto*, Jordan, D. S. & Gilbert, C. H., *Proc. U. S. Nat. Mus.*, 5, 1882: 102-103, not large specimen mentioned on page 104 (description; type-locality: Mazatlan, Mexico; type No. 28167, U. S. Nat. Mus.). Jordan, D. S. & Gilbert, C. H., *Bull. U. S. Fish Comm.*, 2, 1882: 105 (Mazatlan, Mexico; common name).

Eulamia fronto, Evermann, B. W., & Jenkins, O. P., *Proc. U. S. Nat. Mus.*, 14, 1891 (1892): 129 (Guaymas, Mexico; 28 inch specimen).

Carcharinus fronto, ? Jordan, D. S., *Fishes of Sinaloa*, 1895: 382 (erroneous note referring to a large, man-eating shark). Jordan, D. S. & Evermann, B. W., *Fishes North and Middle America*, 1, 1896: 39 (description; length erroneously given as 10 feet). Jordan, D. S., *Proc. U. S. Nat. Mus.*, 8, 1885 (1886): 363 (check-list).

Carcharinus milberti, Garman, S., *The Plagiostomia*, 1913: 133 (synonymy only, in part).

Carcharhinus milberti, Meek, S. E. & Hildebrand, S. F., *Marine Fishes of Panama*, 1, 1923: 38 (synonymy only, in part).

? *Eulamia plumbea*, Fowler, H. W., *Proc. 4th Pac. Sci. Congr., Java*, 1929 3, 1930: 492 (? Mazatlan record).

Discussion: The 704 mm. specimen that we refer to this species agrees well with the description of the 915 mm. type, except for the following: there is but one gill-opening definitely over the pectoral base, and the anterior margin of the pelvic fins is shorter than the distance between the angles of the mouth. However, the general agreement is so close that we have no hesitation in assigning our Costa Rican specimen to *fronto*.

In the original description of *fronto*, based on an adult and a young shark, it is obvious that two species are represented, the first half of the description referring to a fish with an exceptionally large second dorsal fin and narrowly triangular, broad-based teeth. The second half of the

description, in which the body-measurements are admittedly inaccurate, as they were made without instruments, is of a ten-foot shark with much smaller second dorsal fin and serrated teeth. The latter fish may represent a specimen of *Eulamia azureus*. We here delimit the first half of this description, referring to the small specimen designated as the type, as the original description of *fronto*.

Our transfer of the species to the genus *Aprionodon* is based upon the following. Jordan & Gilbert in the original description of *fronto* state: "Edges of teeth appearing minutely serrulate under a lens." This condition is not true of our specimen as even under fairly high power the tooth edges are entire *except* where their rather delicate borders have become irregularly nicked from some external agency.

In order to check on this discrepancy, Dr. Leonard P. Schultz of the U. S. National Museum was asked to examine the teeth of the type specimen of *Carcharias fronto*. He reports: ". . . the teeth do not have serrations, only rough here and there from some external cause."

We thus have evidence from the type and an additional shark that the teeth are smooth and we consequently assign the species to *Aprionodon*. It may be mentioned that *Aprionodon fronto* differs considerably in appearance from the species of *Eulamia* found along the tropical Pacific coast, the similarity in size of the two dorsal fins giving the fish a distinctive appearance. In this it resembles the Atlantic *Hypoprion brevipinnis* and some of the western Pacific species of *Aprionodon*.

Probably as the result of true *fronto* being considered as the young of a large, serrated-toothed shark (a natural conclusion, considering the inference supplied by the two specimens in the original description), Garman synonymized this species and the eastern Pacific *Eulamia azureus* with the Atlantic Ocean *Eulamia milberti*. In this he has been followed by other authors.

***Eulamia* Gill, 1861.**

Key to tropical eastern Pacific species.¹⁸

- 1a. Sides of the body with a band-like continuation of the dark color of the upper surfaces extending backward along the sides to above the pelvic fins, enclosing above it a section of the white of the underparts; tips of fins black; teeth of both jaws narrowly triangular with a broad shoulder-like base, all of the teeth distinctly serrated on their margins; lower teeth considerably narrower than the upper. *aethalorus*
- 1b. Color pattern not as above. Teeth, especially those of the upper jaw, not as above, either broadly triangular, or with one side notched, or with a broad shoulder-like base on one side only.
- 2a. Snout exceptionally long and thin; inter-narial space equal to or only slightly exceeding the length of one of the nostrils; nostril openings almost transverse. *velox*

- 2b. Snout not especially long and narrow; inter-narial space at least two and a half times or more as broad as the length of a nostril.
- 3a. Origin of the 2nd dorsal fin opposite or behind the vertical of the *middle* of the anal fin. *cerdale*
- 3b. Origin of the 2nd dorsal fin opposite or in advance of the *origin* of the anal fin.
- 4a. Snout short and bluntly rounded, the preoral portion 1.66 to 1.9 in the distance between the angles of the mouth; origin of the 2nd dorsal fin conspicuously in advance of that of the anal fin. *azureus*
- 4b. Snout not as short and blunt, the preoral portion slightly less to slightly longer than the width of the mouth, not as short as mentioned above; origin of the 2nd dorsal fin slightly in advance of that of the anal, or directly above.
- 5a. Teeth finely serrate, not notched; origin of the 2nd dorsal fin slightly in advance of the origin of the anal fin. *lamiella*
- 5b. Teeth coarsely serrate, usually notched; origin of 2nd dorsal fin approximately above that of the anal.
- 6a. Tips of some of the fins white. *platyrhynchus*
- 6b. Tips of the fins dusky, never white. *galapagensis*

***Eulamia aethalorus* (Jordan & Gilbert).**

Cazon.

(Plate II, Fig. 2).

Range: Pacific mainland from Lower California and the Gulf of California to Peru. (Mexico: Concepcion Bay, La Paz, Arena Bank, Mazatlan; Guatemala: Chiapam; Panama: Panama Bay; Peru: Lobos de Afuera Island).

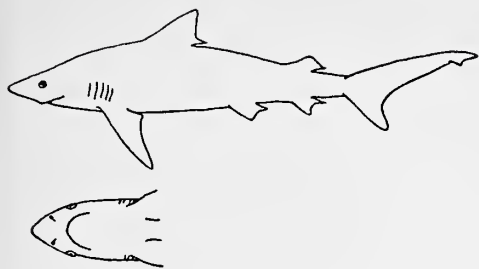
Field Characters: A medium-sized shark with conspicuous black tips to the fins and a dark band along the sides as far back as the pelvic fins, enclosing above it a section of the white underparts. Teeth of the jaws narrowly triangular with broad, shoulder-like basal portions; upper teeth finely serrate, lower teeth almost

¹⁸ The difficulties of identifying some of the species of this genus have long been manifest, and during the *Zaca* and *Arcturus* expeditions this fact was appreciated more than ever when sharks too large to preserve were caught. While working over our preserved material, it became even more evident that the synonymies and concepts of the species of *Eulamia* of the Pacific were far from being clean-cut and exact.

In an attempt to straighten out the confusion that existed in our minds while reviewing the literature of the sharks of the eastern tropical Pacific, we decided to discard all references that merged the eastern Pacific forms with species of supposedly world-wide distribution and to start over again with types and original descriptions of the species that have been described from the region under discussion. We have not attempted to recorelate the eastern Pacific forms with species from other regions. These littoral species seem to represent valid local species.

The change with age of many characters in this group is considerable, and because of this we have given the exact length of each specimen discussed.

Two imperfectly described species that apparently belong to the genus *Eulamia* are described from the west coast of South America. We have not been able to satisfy ourselves as to their relationships. They are *Carcharias robustus* Philippi (*Ann. Univer. Chile*, 93, 1896: 389) and *Eulamia philippi* Fowler, described as *Carcharias brachyrhynchus* by Philippi (*Ann. Univer. Chile*, 71, 1887: 540) and renamed by Fowler.



Text-figure 15.

smooth. (Illustration after Meek & Hildebrand, 1923: 850 mm.)

Color: Dusky bronze above; dead white on lower snout, head and lower surfaces of the pectoral fins; belly, first dorsal and anal fins grayish; the dusky bronze covers the upper surface of the pectoral fins and extends back in a long narrowing band along the lower sides to above the pelvic fins, enclosing a wider band of whitish from the sides of the peduncle forward, dying out at the vertical of the center of the first dorsal fin. Pelvic fins above, and caudal fin bronzy dusky like the back. Paired fins white below with jet black tips, the black extending down the posterior edge of the pectorals. Posterior edge of the first dorsal black; distal half of second dorsal black; posterior edge of caudal black. Anal fin pale with a large black spot at the tip. Iris pale brassy. (2,070 mm. fish.)

In the embryos from the specimen just described, the color pattern of the sides is even more marked than in the adult. They also possess conspicuously black-tipped fins.

Size and Weight: Grows to at least seven feet. A 2,070 mm. (81 inches) shark weighed 123 pounds. A 630 mm. embryo weighed 3 pounds.

Parasites: Eighteen copepod parasites, *Alebiaon* sp. taken from this species plus a specimen of *Racineia aries*, from the gills.

Food: This shark took dolphin-fish bait while it was associated with several other sharks in the vicinity of a school of hundreds of large crevalle (*Caranx caninus*). In the stomach of the shark were 24 California sardines (*Sardinia caerulea*).

Breeding: Four embryos averaging 630-650 mm. in length were taken from the 2,070 mm. adult; they were close to being born.

These full-grown embryo sharks were roughly one-third the total length of the adult. Twenty-four comparative measurements of mother and young showed a slight increase in the embryos in relative lengths of the predorsal part of the fish, such as snout to mouth, snout to pectoral, snout to first dorsal fin. The eye was somewhat larger. The pectorals were slightly smaller as was the second dorsal, and the depth was proportionately less. On the whole, however, there was an astonishing agreement in the proportions of the mother and unborn offspring.

This absence of marked dissimilarity in proportions seems to find its explanation in the total lack of larval or real adolescent life. These embryos, when freed from the mother and the umbilical cord, straightway swam off, showing perfect correlation, avoiding the sides and bottom of a large tub, snapping at anything offered to them and apparently functioning in almost every way that a shark requires in order immediately to begin a successful career in the open sea. At the first impact of the outside world these embryos are perfect sharks in miniature, quite unlike the condition of those fish which hatch from eggs near shore or the bottom of shallow waters.

Study Material: 4 specimens. Mexico: Arena Bank, Lower California, 3, adult female (teeth saved) and two young (25,471, 25,472, 25,472B.), 2,070, 630, 650 mm., April 30, 1936, adult captured on rod and line with sailfish bait; 1, Concepcion Bay, Lower California (U. S. Nat. Mus. 46851), collected by the *Albatross*.

References: *Carcharias aethalorus*, Jordan, D. S. & Gilbert, C. H., *Proc. U. S. Nat. Mus.*, 5, 1882: 104 (original description, color; type-locality: Mazatlan, Mexico). Jordan, D. S. & Gilbert, C. H., *Bull. U. S. Fish Comm.*, 2, 1882: 105 (Mazatlan, Mexico), 109 (Panama). Gilbert, C. H. & Starks, E. C., *Fishes of Panama Bay*, 1904: 9 (teeth, claspers, proportions; Panama), 207 (distribution, Gulf of California).

Carcharhinus aethalorus, Jordan, D. S., *Proc. U. S. Nat. Mus.*, 8, 1885 (1886): 363 (check-list). Jordan, D. S., *Fishes of Sinaloa*, 1895: 383 (relationship with *limbatus*). Jordan, D. S. & Evermann, B. W., *Fishes of North and Middle America*, 1, 1896: 40 (description, range).

Carcharhinus aethalorus, Garman, S., *Bull. Mus. Comp. Zool.*, 46 (12) 1906: 229 (Panama).

Carcharias limbatus, Günther, A., *Cat. Fishes Brit. Mus.*, 8, 1870: 373-374 (Reference to specimen from Chiapam only: Guatemala; refers to *maculipinnis* reference).

Carcharhinus limbatus, Garman, S., *The Plagiostomia*, 1913: 127 (synonymy referring to *aethalorus*).

Carcharhinus limbatus, Pellegrin, J., *Bull. Mus. Hist. Nat. Paris*, 7, 1901: 161 (Gulf of California). Nichols, J. T. & Murphy, R. C., *Bull. Amer. Mus. Nat. Hist.*, 46, 1922: 504 (jaw from Lobos de Tierra, Peru). Meek, S. E., & Hildebrand, S. F., *Marine Fishes of Panama*, 1, 1923: 41 (description; synonymy referring to *aethalorus*; Panama).

Carcharhinus natator, Meek, S. E. & Hildebrand, S. F., *Marine Fishes of Panama*, 1, 1923: 41, Plate 1, fig. 1 (original description, color, figure; type locality, Panama City, Panama; type No. 79310, U. S. Nat. Mus.).

Carcharias maculipinna (not of Poey) Günther, A., *Trans. Zool. Soc. London*, 6, 1868: 490, teeth, dimensions; Guatemala, Chiapam.

Discussion: We have two embryos of this species at hand that agree excellently with the original description of *aethalorus*, and the teeth,

field description, measurements and photographs of the 2,070 mm. parent; these specimens were taken at Arena Bank, Lower California, 160 miles N. by W. of Mazatlan, the type locality of the species. The embryos differ from the original description in having the base of the first dorsal fin slightly greater than the height (the opposite is true of the parent) and in the caudal fin being 29% of the length instead of 25% (the parent has the same measurement 27%).

Comparing the adult female with the original description of *aethalorus*, which is of a male 30 inches or 762 mm. in length, the following slight differences are observed: the preoral distance is 81% of the mouth width instead of being equal; the teeth are $\frac{30}{30}$ instead of $\frac{24}{24}$ (Panama specimens are recorded as $\frac{29}{29}$; the base of the first dorsal is 1.2 in the interorbital width, not equal; the second dorsal fin base is 5.2 instead of 4 in the interdorsal space; the base of the 2nd dorsal fin is 36% (instead of 50%) of the base of the first dorsal (in our embryos this distance is approximately 50%).

Carcharinus natator, described by Meek & Hildebrand from Panama Bay, we believe to be identical with *aethalorus*. The characters differentiating the two forms overlap when our embryos and large specimens are compared with the descriptions. *Eulamia aethalorus* and *nator* both possess the same type of teeth, general proportions and relationships of fins. It must be admitted that our specimens do not show the peculiar form of the snout, when viewed from the side, that is shown for *nator* in Meek & Hildebrand's original illustration of their type. This peculiar conformation may have been caused by preservation.

As far as coloration is concerned the two forms are the same. Both have conspicuous black-tipped fins and possess a distinctive color pattern on the sides. In the original description of *nator* two ill-defined dark bands are mentioned, and in our two Gulf of California specimens these bands are strongly evident. However, the uppermost of these two bands is merely an intensification of the lower border of the dark pigmentation of the dorsal surfaces and in the adult female this band has completely merged with the dark of the upper surfaces, leaving only the shorter, lower band conspicuously outlined. This band is mentioned above in the description under *Color* and can indistinctly be seen in the illustration; it was plainly visible in life and is so mentioned in our field notes.

This shark is closely related to *Eulamia limbatus* of the Atlantic.

Eulamia velox (Gilbert).

(Plate II, Fig. 3).



Text-figure 16.

Range: Lower California, Costa Rica and Panama Bay. (Mexico: Santo Domingo Point and Cape San Lucas, Lower California; Costa Rica: Port Culebra; Panama: Panama Bay. Previously known from three specimens taken in Panama Bay; our two specimens extend the range some 2,100 miles northeastward along the coast.)

Field Characters: A small elongate shark with a long narrow snout; nostrils large, the interdorsal space narrow, about equal, more or less, to the relatively large nostril openings. (Illustration after Gilbert & Starks, 1904: 1200 mm.)

Color: Bronzy brown above, changing to silvery iridescence and dead white below. Second dorsal fin with a dusky tip.

Size: The largest recorded specimen is 1,200 mm. (47½ inches).

Food: The stomach of our Santa Domingo specimen contained the chelae of a crab, *Ovalipes punctatus*.

Study Material: 3 specimens. Mexico: Santo Domingo Point, Gulf of California, 1 female (25264), 945 mm., April 16, 1936, hand-line; San Lucas Bay, Lower California, 1, April 23, 1936, hand-line. Costa Rica: Port Culebra, 1 female (26134) 735 mm., Jan. 25, 1938.

References: *Carcharhinus velox*, Gilbert, C. H., in Jordan, D. S. & Evermann, B. W., Fishes North and Middle America, 3, 1898: 2747 (original description, color; type locality, Panama; type, No. 11893, University Museum, Stanford University). Meek, S. E. & Hildebrand, S. F., Marine Fishes of Panama, 1, 1923: 45 (description, Panama market).

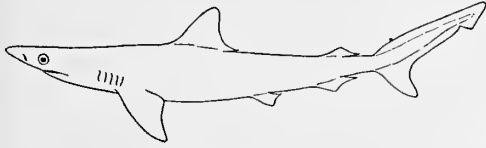
Carcharias velox, Gilbert, C. H. & Starks, E. C., Fishes of Panama Bay, 1904: 5 (deposition of type) 9, Plate 1, fig. 3 (copy of original description, figure), 207 (distribution).

Carcharinus velox, Garman, S., The Plagiostomia, 1913: 130 (description).

Discussion: These are the fourth, fifth and sixth recorded specimens of this rare species. The previously known ones are the type, taken by

Gilbert in Panama Bay, and two specimens taken by Meek & Hildebrand, also at Panama. The present specimens agree perfectly with Gilbert's description of a 1,200 mm. fish and with the description given by Meek & Hildebrand.

Eulamia cerdale (Gilbert).



Text-figure 17.

Range: Mexico to Ecuador and the Galápagos Islands. (Mexico: "coast of Mexico"—Kumada & Hiyama; Panama: Panama Bay, and at sea 130 miles S. W. of Burica Point, Panama; Colombia: Buenaventura; Ecuador: Guayaquil; Galápagos Islands, South Seymour and Albe-Marle. Also known, according to Meek & Hildebrand, from the Atlantic side of the Isthmus of Panama.)

Field Characters: A small shark lacking conspicuous folds and grooves about the angles of the mouth and with the origin of the 2nd dorsal fin at or behind the vertical of the middle of the anal fin; teeth serrate, those in the upper jaw broader and more oblique than those in the lower and with broader bases; a rather prominent notch behind the large triangular cusp of the lateral teeth in the upper jaw. Bluish-gray above, pale below. (Illustration after Kumada & Hiyama, 1937: 537 mm.)

Size: Herre's largest specimen was 1,235 mm. (49 inches). This, judging by Meek & Hildebrand, is a small species.

Study Material: 1 specimen, Panama (U. S. Nat. Mus. 50438) collected by Gilbert.

References: *Carcharinus* sp. indes., Jordan, D. S., *Proc. U. S. Nat. Mus.*, 8, 1885 (1886): 363 (name only; specimen destroyed by fire before publication of description).

Carcharhinus cerdale, Gilbert, C. H., in Jordan, D. S. & Evermann, B. W., *Fishes of North and Middle America*, 3, 1896: 2746 (original description, color, abundance, comparison with *aethalurus*; type locality: Panama; type No. 11,884, University Museum, Stanford University). Meek, S. E. & Hildebrand, S. F., *Marine Fishes of Panama*, 1, 1923: 47 (description, synonymy, color, discussion of Atlantic coast relative, range).

Carcharias cerdale, Gilbert, C. H. & Starks, E. C., *Fishes of Panama Bay*, 1904: 5 (number and disposition of type), 10, Plate 2, fig. 4 (description, color, abundance, comparison with *aethalurus*, figure; Panama). Starks, E. C., *Proc. U. S. Nat. Mus.*, 30, 1906: 762 (range), 763 (Ecuador).

Carcharinus cerdale, Garman, S., *Bull. Mus. Comp. Zool.*, 46, 1906: 229 (Panama). Herre,

A. W., *Field Mus. Nat. Hist., Zool. Ser.*, 21, 1936: 22 (synonymy, short description, color, size; Galápagos Islands and at sea).

Charcharhinus cerdale, Wilson, C., *Ann. Carn. Mus.*, 10, 1916: 58 (Colombia, Ecuador).

Eulamia cerdale, Fowler, H. W., *Acad. Nat. Sci. Phila., Monograph No. 2*, 1938: 249 (mentioned in check-list of Galápagos Island fishes).

Carcharinus menisorrah (in part) Garman, S., *The Plagiostomia*, 1913: 135 (synonymy referring to *cerdale* only).

Carcharhinus lamiella (not of Jordan & Gilbert), Kumada, T., & Hiyama, Y., *Marine Fishes Pacific Coast of Mexico*, 1937: 16, Plate 48 (short description, referring to almost any shark; figure referable to *cerdale*).

Discussion: The figure of Kumada & Hiyama agrees almost entirely with the original figure of *cerdale*, and even though this record extends the distribution of the species to an indefinite locality on the coast of Mexico, we consider this extension justified.

Eulamia azureus (Gilbert & Starks).



Text-figure 18.

Range: Mexico ?, Costa Rica, Panama and Ecuador. (? Mexico: Mazatlan; Costa Rica: Piedra Blanca Bay; Panama: Panama Bay; Ecuador: Guayaquil.)

Field Characters: A large shark with broadly rounded head and with the origin of the 2nd dorsal fin well in advance of that of the anal; teeth of the upper jaw broadly triangular with their inner margins oblique and usually slightly convex, the outer margins concave or sometimes with a very slight notch; lower jaw with much narrower, triangular teeth on a broad base; upper jaw teeth serrate along entire border, lower teeth more finely serrate, the serrations less prominent and sometimes absent on the shoulders of the teeth. (Illustration after Gilbert & Starks, 1904: 920 mm.)

Color: Dark gray above, white below; fins with dusky tips.

Size and Weight: Our 2,820 mm. (9 feet, 3 inches) shark weighed 210 pounds.

Food: This species at times feeds upon sting rays, as the spines of four of these animals were found embedded in the skin of the jaws of our shark.

Parasites: Two leeches, *Pontobdella muricata* (Linn.), were taken from our Piedra Blanca

shark. A copepod parasite, *Rocinela aries*, taken from the gills.

Study Material: 2 specimens. Costa Rica: Piedra Blanca Bay, 1 male (26148), 2,820 mm., Feb. 4, 1938, harpooned. Ecuador: Guayaquil, 1 male (U. S. Nat. Mus. 53528) 1025 mm.

References: *Carcharias azureus*, Gilbert, C. H. & Starks, E. C., *Fishes of Panama Bay*, 1904: 5 (type and disposition), 11, Plate 2, fig. 5 (original description, color, figure; type locality, Panama; type No. 11884, University Museum, Stanford University; comparison with *C. nicaraguensis*; size of male with undeveloped claspers), 207 (distribution). Starks, E. C., *Proc. U. S. Nat. Mus.*, 30, 1906: 762 (distribution), 763 (Guayaquil, Ecuador; specimen compared with type). Garman, S., *Bull. Mus. Comp. Zool.*, 46, 1906: 229 (Panama).

Carcharias milberti, Garman, S., *The Plagiostomia*, 1913: 133 (references referring to *azureus* only; not description). Meek, S. E. & Hildebrand, S. F., *Marine Fishes of Panama*, 1, 1923: 38 (references referring to Pacific specimens and description of Ecuadorian skin on pp. 39-40; description).

Eulamia plumbea, ? Fowler, H. W., *Proc. 4th Pac. Sci. Congr.*, Java 1929, 3, 1930: 492 (? Panama record).

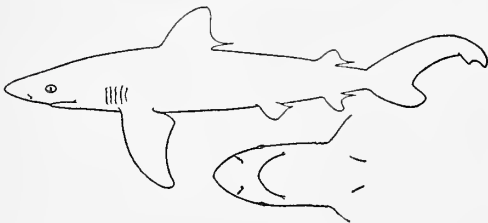
Discussion: We have had for comparison with our Costa Rican specimen, the 1,025 mm. shark recorded by Starks from Ecuador; we find that they are the same. The Ecuadorian shark was compared with the type by Starks and partially redescribed by Meek & Hildebrand.

The large specimen recorded under the original description of *Carcharias fronto* (*Proc. U. S. Nat. Mus.*, 5: 103-104) may be this species. As is stated, all of the measurements were taken without instruments and are questionable. However, there are no strong points of difference and the description of the teeth is in agreement with our specimen.

This species is closely related to the Atlantic *Eulamia milberti*.

***Eulamia lamiella* (Jordan & Gilbert).**

Bay Shark; Tiburon.



Text-figure 19.

Range: Southern California to the Gulf of California. (Mexico: Concepcion Point and Mazatlan.)

Field Characters: Broad-snouted shark growing to 15 feet, with origin of the 2nd dorsal fin slightly in advance of that of anal, preoral portion of the snout slightly less or slightly greater than the width of the mouth; teeth triangular, not notched, with fine serrations; grayish, tips of the pectoral fins slightly dusky. (Illustration from specimen No. 25263: 840 mm.)

Color: Dark gray above, grayish-white below; no markings; tips of the pectorals slightly dusky, the upper side dark; all other fins plain.

The color of six embryos averaging 840 mm. in length, was as follows: Above slaty-black with sheen; dead white below; sides iridescent, changing from purplish to bronze to silvery; first dorsal dark bronze-gray, upper posterior margin broadly black; second dorsal same with the distal half black, dark at base with large, black distal spot, white below with corresponding distal black spot; pelvics pale gray with black tip; anal same with larger black spot; caudal with entire outline narrowly jet black, tips of lobes black, the rest gray. Iris silvery with greenish tinge.

Size and Weight: Grows to 15 feet. A 2,616 mm. (8 foot 6 inch) shark weighed 270 pounds.

Abundance: Rare north of San Diego, fairly common in San Diego Bay and southward.

Parasites: Five copepod parasites, *Alebion* sp., taken from this species.

Breeding: Our 2,616 mm. female had six young on April 16, 1936, about to be born. The young averaged around 840 mm. in length and were from 4 pounds 4 ounces to 8 pounds 12 ounces in weight. The litter was composed of one male and five females.

Study Material: 3 specimens. Mexico: Concepcion Point, Lower California, 1 adult female, not saved (25262) and 1 embryo, saved (25263), 2,616 and 840 mm., April 16, 1936, caught on hook and line. The type in the U. S. National Museum was also examined.

References: *Eulamia lamia*, Jordan, D. S., & Gilbert, C. H., *Proc. U. S. Nat. Mus.*, 4, 1881: 32 (First recording of specimen which later became the type of *lamiella*).

Carcharias lamiella, Jordan, D. S., & Gilbert, C. H., *Proc. U. S. Nat. Mus.*, 5, 1882: 110 (original description, color; type locality, San Diego, California; type, No. 27366, U. S. Nat. Mus.).

Carcharhinus lamiella, Jordan, D. S., *Fishes of Sinaloa*, 1895: 382 (Mazatlan, Mexico; deformed tail). Jordan, D. S., & Evermann, B. W., *Fishes North and Middle America*, 1, 1896: 37 (description; range).

Carcharhinus commersonii (in part), Garman, S., *The Plagiostomia*, 1913: 140 (synonymy referring to *lamiella* only). Meek, S. E., & Hildebrand, S. F., *Marine Fishes of Panama*, 1, 1923: 43 (synonymy referring to *lamiella* only, not description).

Eulamia commersonii (in part), Fowler, H. W.,

Proc. 4th Pac. Sci. Cong., Java, 1929 (1930): 493 (localities referring to *lamiella* only; references include *platyrhynchus*).

Discussion: The relationship of this species, and of *platyrhynchus* and *galapagensis* are not as clearly defined as might be desired. Thus we find that the original description of *platyrhynchus* states the following: "From *lamiella* it differs in the notched teeth and the anterior position of the first dorsal." The type of *lamiella*, however, is not in accord with its original description and the first dorsal fin is much further forward than is stated. It is actually the same in position in both species. Relative fin positions are thus invalid as distinguishing specimens of *lamiella* and *platyrhynchus*.

The teeth serrations in the two species constitute a real difference. Thus in *lamiella*, of which we have examined adult and young in addition to the young type, the serrations on the teeth are very fine, while in the more or less equal-sized specimen of *platyrhynchus* and the eight specimens of the closely related *galapagensis* the serrations are exceptionally coarse.

As far as *galapagensis* and *platyrhynchus* are concerned, the original description of the former states: "The same in every respect as *Carcharias platyrhynchus* (Gilbert) except that the fins at all ages are of uniform coloration with the body, being never margined with white." In the materials that we have examined the presence or absence of white fin tips is clearly demonstrable, and the specimens are easily assigned to one species or the other on that basis, but the materials also indicate that further studies are needed involving series of young and old before these two forms are clearly defined. There seems to be considerable variation in our series of *galapagensis*, but owing to differences in size and lack of pertinent sized material we are unable to correlate these variations.

It is of interest that, so far, all locality records of *lamiella* are continental, while those of *platyrhynchus* and *galapagensis*, with the exception of a single questionable continental record for each species, are off-shore and insular.

Carcharhinus lamiella possesses a low dermal keel between the first and second dorsal fins.

This species has usually been synonymized under the Atlantic and Mediterranean *Eulamia commersonii*.

Eulamia platyrhynchus Gilbert.

White-tipped Shark.



Text-figure 20.

Range: Mexico: Magdalena Bay and Mazatlan (?), Revillagigedo Islands; Cocos Island, Clipperton Island, Galápagos Islands and at sea, 230 miles N. W. of Clipperton Island.

Field Characters: Small to medium-sized, broad-snouted sharks with the origin of the 2nd dorsal fin approximately above that of the anal; teeth of the upper jaw triangular with the outer margin notched or concave, serrated; lower teeth erect, narrow, serrulate. Gray, with the tips of the dorsal, pectoral and caudal fins tipped with white. (Illustration from Specimen No. 17,521, Field Museum; 700 mm.)

Color: Dorsal fins, sometimes only the first dorsal, tipped with white; occasionally with the dorsal and pectoral fins tipped and posteriorly bordered with white, the marginal parts of the fins pale.

Size: Grows to nine feet.

Abundance: A locally abundant fish. Beebe reports 16, five- to six-foot sharks seen while diving in one spot at Cocos Island.

Food: Fish; a new species, *Pontinus strigatus*, was taken from the stomach of this species. There is also a record of *Diodon hystrix*.

Study Materials: 2 specimens. Clarion Island, 1 male (25594) 1,524 mm., May 10, 1936, hand line, teeth preserved and photograph. 1, Tagus Cove, Galápagos Islands, 700 mm. (Field Mus. Nat. Hist. 17521), Jan. 9, 1929.

References: *Eulamia (Platypodon) platyrhynchus*, Gilbert, C. H., *Proc. U. S. Nat. Mus.*, 14, 1891: (1892): 543 (original description: part refers to *galapagensis*: Clarion Island, Magdalena Bay).

Carcharias platyrhynchus, Snodgrass, R. E., & Heller, E., *Proc. Wash. Acad. Sci.*, 6, 1905: 344 (Clarion Island, near Clipperton Island, color note), 414 (280 mm. *Diodon hystrix* from stomach). Beebe, W., *The Arcturus Adventure*, G. P. Putnam's Sons 1925: 246, 435 (sociability), 302, 435 (habits) 412 (Cocos Island).

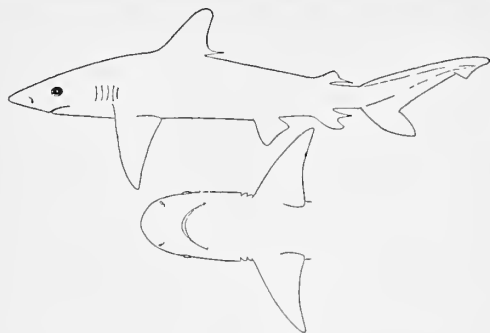
Carcharinus platyrhynchus, Herre, A. W., *Field Mus. Nat. Hist., Zool. Ser.*, 21, 1936: 23 (brief note on proportions, color and abundance; Cocos and Galápagos Islands).

Carcharhinus platyrhynchus, Jordan, D. S., & McGregor, R. C., *Rep't. U. S. Fish Comm.*, 1898 (1899): 274 (Clarion Island). Jordan, D. S. & Evermann, B. W., *Fishes North and Middle America*, 1, 1896: 36 (description in part, remainder belongs to *galapagensis*). Heller, E., & Snodgrass, R. E., *Proc. Wash. Acad. Sci.*, 5, 1903: 209 (Galápagos Is., type of *Pontinus strigatus* taken from stomach).

Carcharinus commersonii (in part) Garman, S., *The Plagiostomia*, 1913: 140 (synonymy referring to *platyrhynchus* only). Meek, S. E., & Hildebrand, S. F., *Marine Fishes Panama*, 1, 1923: 43 (synonymy referring to *platyrhynchus*).

Carcharias sp. incog., Jordan, D. S., & Gilbert, C. H., *Proc. U. S. Nat. Mus.*, 5 1882 (1883): 107 (teeth of Mazatlan fish, may refer to this species).

Discussion: See under *C. lamiella*.

Eulamia galapagensis (Snodgrass & Heller).

Text-figure 21.

Range: Mexico: Lower California (?), Clarion Island; Clipperton Island; Cocos and Galápagos Islands; and at sea 75 miles northeast of Malpelo Island.

Field Characters: Small to medium sized, broad-snouted sharks with the 2nd dorsal fin origin approximately above that of the anal. Teeth of the upper jaw triangular, notched or concave on the outer margin and strongly serrated. Lower teeth, narrow, erect, with much smaller serrations. Color uniform gray, the tips of the fins dusky, never tipped with white. (Illustration from specimen No. 5257: 798 mm.)

Color: Iris silvery-gray.

Abundance: Herre states: "This shark swarms in the waters of the Galápagos Islands and about Cocos Island. I have never seen sharks of this genus in such abundance as in these two localities. A great many of this species were caught by hook and line or harpooned. . ."

Size and Weight: Grows to 8 feet. A 790 mm. (31 inches) fish weighed 7 pounds and a 1,260 mm. (50 inch) shark weighed 24 pounds.

Study Material: 8 specimens. Clarion Island, 3 males and 1 female (25498, 25674, 25675, 25676; 590, 735, 768 and 842 mm.) May 10, 1936, hook and line and harpooned. Tower Island, Galápagos Islands, 2 (5254, 5257) 790, 798 mm., April 8, 1925, harpooned. Galápagos Islands, 2 (Field Museum No. 17520) Jan. 9, 1929. Cocos Island, 1 (Field Museum No. 17519), Jan. 2, 1929.

References: *Carcharias galapagensis*, Snodgrass, R. E., & Heller, E., *Proc. Wash. Acad. Sci.*, 6, 1905: 343 (original description; short synonymy; range, size, food; type locality: Galápagos Islands; type No. 12324, University Museum, Stanford University) Beebe, W., *The Arcturus Adventure*, G. P. Putnam's Sons, New York, 1926: 184, 302 (color of eye), 412 (4-foot specimen harpooned, food; Galápagos Islands).

Eulamia galapagensis, Fowler, H. W., *Proc. U. S. Nat. Mus.*, 80 (6) 1932: 1 (teeth; Galápagos Islands). Fowler, H. W., *Acad. Nat. Sci. Phila.*, *Monograph* No. 2, 1938: 13 (jaw and ventral fins of female from 75 miles northeast of Malpelo

Island), 19 (references; jaws, ventral fins and section of skin; Galápagos Islands), 248 (check-list; range among Galápagos Islands).

Carcharinus galapagensis, Herre, A. W., *Field Mus. Nat. Hist., Zool. Ser.*, 21, 1936: 22 (color, abundance, size; Galápagos and Cocos Islands).

Eulamia lamiella (?), Jordan, D. S., & Bollman, C. H., *Proc. U. S. Nat. Mus.*, 12, 1889: 179 (name only; Galápagos Islands).

Eulamia (Platyodon) platyrhynchus (in part), Gilbert, C. H., *Proc. U. S. Nat. Mus.*, 14, 1891 (1892): 543 (non-white-margined specimens; Revillagigedo Islands).

Carcharhinus platyrhynchus, Jordan, D. S., & Evermann, B. W. (in part), *Fishes North and Middle America*, 1, 1896: 36 (part of description referring to *galapagensis*).

Discussion: See discussion under *lamiella*.

Scoliodon Müller & Henle, 1837.*Scoliodon longurio* (Jordan & Gilbert).

Text-figure 22.

Range: Gulf of California, and coast of Mexico, Panama. (Mexico: Santa Inez Bay, Guaymas, Mazatlan, San Lucas Bay, Banderas Bay, Tangola-Tangola; Panama: Panama Bay.)

Field Characters: A small, sharp-snouted shark with origin of the second dorsal fin above or posterior to the middle of the base of the anal fin; conspicuous labial fold and groove at the angle of the mouth, paralleling the jaw and extending forward about one third the distance from the gape to the front of the mouth. (Illustration after Meek & Hildebrand, 1923.)

Color: Gray with a bluish tinge above, white below; tips of fins margined with dusky.

Size and Weight: Grows to 1,068 mm. (42½ inches). A specimen of this size weighed nine pounds.

Local Distribution: All of the records and our specimens seem to indicate that this is a bay shark.

Abundance: Locally abundant, based on Jordan's and our experiences.

Study Materials: 2 specimens. Mexico: Santa Inez Bay (24,993) 980 mm., April 13, 1936, hand-line; Puerto Vallarte, Banderas Bay, 1 (27,054), 815 mm., Nov. 15, 1937, hand line (teeth saved). We have also examined six specimens from San Lucas Bay, and an additional one from Santa Inez Bay.

References: Carcharias longurio, Jordan, D. S., & Gilbert, C. H., *Proc. U. S. Nat. Mus.*, 5, 1882: 106 (original description, color; type locality: Mazatlan, Mexico; types, Nos. 28,306, 28,330, 28,331, 29,451, 29,551, U. S. National Museum).

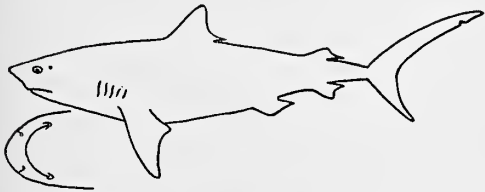
Carcharhinus longurio, Jordan, D. S., *Proc. U. S. Nat. Mus.*, 8, 1885 (1886): 363 (check-list).

Scoliodon longurio, Jordan, D. S., & Gilbert, C. H., *Bull. U. S. Fish. Comm.*, 2, 1882: 105 (Mazatlan, Mexico). Evermann, B. W., & Jenkins, O. P., *Proc. U. S. Nat. Mus.*, 14, 1891 (1892): 130 (references; Guaymas, Mexico). Jordan, D. S., *Fishes of Sinaloa*, 1895: 382 (common at Mazatlan). Jordan, D. S., & Evermann, B. W., *Fishes North and Middle America*, 1, 1896: 42 (description). Jordan, D. S., & Evermann, B. W., *Fishes North and Middle America*, 3, 1898: 2748 (note on teeth and size of first dorsal). Gilbert, C. H., & Starks, E. C., *Fishes of Panama Bay*, 1904: 12 (6 specimens from Panama; note on porpoctions and teeth), 207 (range; Panama and Gulf of California). Garman, S., *The Plagiostomia*, 1913: 114 (short synonymy, description, color; range). Meek, S. E., & Hildebrand, S. F., *Marine Fishes of Panama*, 1, 1923: 52, Plate 2, fig. 1 (short synonymy, description, color, figure, comparison with types, claspers; Panama fish market, 525 and 700 mm. males). Breder, C. M., Jr., *Bull. Bingham Oceanogr. Coll.*, 2 (1), 1928: 3 (specimen from unknown locality). Seale, A., *Allan Hancock Pacific Expeditions*, 9 (1), 1940: 1 (490 mm. specimen, Tangola-Tangola, Mexico).

Galeocerdo Müller & Henle, 1838.

Galeocerdo arcticus (Faber).

Tiger Shark.



Text-figure 23.

Range: Tropical and temperate seas, north rarely to 70°. In the eastern coastal Pacific north to San Diego. (Mexico: Gulf of California, Santa Inez Bay, Concepcion Bay, Guaymas, Mazatlan, Tangola-Tangola; Guatemala: San Jose de Guatemala; Costa Rica: Golfito; Panama: Panama Bay and Pearl Islands; Clarion Island; Clipperton Island; Cocos Island; Galápagos Islands: Narborough, Albemarle and Guy Fawkes Island.)

Field Characters: A large, heavy shark with blunt head; caudal fin large with very long upper lobe, and well-developed lateral keels at base; teeth alike in both jaws, semicircular, with a

deep notch and coarsely serrated edges, the tips turned obliquely outward. (Illustration after Norman, 1937.)

Color: Dark gray above, white below; numerous black, rectangular spots on body and fins, usually forming vertical bars, becoming rounded on upper caudal lobe. This pattern is lost on older individuals. Iris greenish-brown.

Size: Reaches a length of at least 20 feet (Record of 30 feet unconfirmed).

Weight: A shark of 1,625 mm. (5 feet, 4 inches) weighed 137 pounds; 1, 3,073 mm. (10 feet, 1 inch) 366 pounds (liver 97 lbs. 26% of whole); 1, 3,200 mm. (10 feet, 6 inches) 505 pounds; 1, 3,886 mm. (12 feet, 9 inches) 780 pounds (liver 188 lbs., 24% of whole).

Local Distribution: Well offshore and in bays of only four fathoms depth.

Abundance: Tiger sharks are fairly common throughout the area under consideration.

Food: Almost any invertebrate or vertebrate of sufficient size may find a place in the diet of this shark. Our list is as follows: garbage (3 stomachs), octopus (400 mm.), *Heterodontus quoyi* (375 mm.), sting rays (7 in 3 stomachs, four of them *Urobatis halleri*), *Gymnosarda allletterata* (400 mm.), *Mycteroperca jordani* (600 mm.), *Diodon holacanthus* (200 mm.), *Ogcocephalus* sp. (150 mm.), *Iguana iguana* (1,371 mm.), *Chelone mydas*, full of eggs (760 mm.), feathers (3 stomachs), 2 Clarion shearwaters, *Puffinus auricularis*; and Galápagos sea-lion pup, *Otaria jubata*.

Parasites: Two copepods taken from near the gills, *Pandarus satyra* Dana and *Rocincla arics*.

Study Material: Definite notes were made on 11 tiger sharks, and several other individuals were seen. All were hooked from the deck of vessels. Mexico: Santa Inez Bay, 1 (24,894), 1,625 mm., April 9, 1936; Santa Inez Bay, 1, 1,422 mm., April 9, 1936; Concepcion Bay, 1, 1,625 mm., April 16, 1936; Clarion Island, 1, ca. 1,400 mm., May 11, 1936; Clarion Island, 1 (25,655), 3,886 mm., May 13, 1936; Tangola-Tangola Bay, 1 (26,051), 3,073 mm., Dec. 10, 1937; Costa Rica: Golfito, 1 (26,184), 3,200 mm., March 8, 1938; Panama: Pearl Islands, 1, 1,882 mm., June 27, 1933; Galápagos Islands: Tagus Cove, Albermarle Island, 1 (6159), 2,133 mm., June 7, 1925; Guy Fawkes Islands, 1, "18 or 20 feet," March 31, 1923, "seen to kill and devour a sea-lion pup"; Cocos Island: 1, "15 to 18 feet," May 17, 1925.

References: Squalus arcticus, Faber, F., *Fische Islands*, 1829: 17 (Iceland and neighboring seas).

Galeocerdo tigrinus, Jordan, D. S., & Gilbert, C. H., *Bull. U. S. Fish Comm.*, 2, 1882 (1883): 112 (San Jose de Guatemala). Gilbert, C. H., *Bull. U. S. Fish Comm.*, 2, 1882 (1883): 105 (Mazatlan, Mexico). Pellegrin, J., *Bull. Mus. Hist. Nat., Paris*, 7, 1901: 161, 166 (Gulf of California, danger to man). Snodgrass, R. E., & Heller, E., *Proc. Wash. Acad.*, 6, 1905: 342 (Albemarle and Narborough Islands, Galápagos

Islands). Fowler, H. W., *Proc. Acad. Nat. Sci. Phila.*, 60, 1908: 61 (jaws from Guaymas, Mexico). Beebe, W., "Galapagos: World's End," New York, 1924: 201, 434 (Guy Fawkes Islands, Galápagos; eating sea-lion pup).

Galeocerdo maculatus, Jordan, D. S., & Bollman, C. H., *Proc. U. S. Nat. Mus.*, 12, 1890: 179 (Panama).

Galeocerdo arcticus, Meek, S. E., & Hildebrand, S. F., *Marine Fishes of Panama*, 1, 1923: 56 (once taken on the Pacific Coast by the *Albatross*). Beebe, W., "The Arcturus Adventure," New York, 1926: 247, 435 (Cocos Island). Breder, C. M., Jr., *Bull. Bingham Oceano. Coll.*, 2 (1), 1928: 3 (specimen from unknown locality). Schmitt, W. L., *Annotated List of Fishes, Presidential Cruise, 1938*, privately printed, 1938: v (Weights; Cocos, Clipperton, and Galápagos Islands).

Galeorhinus Blainville, 1816.

We have no material referable to this genus. It is evident from the confused literature that careful study should be made of the relationships of the northern *Galeorhinus zyopterus* and of the specimens reported from Peru and Chile as *zyopterus*,¹⁹ *galeus*,²⁰ *molinae*,²¹ and *chilensis*.²² Fowler²³ places all of these records under the name *galeus*.

Apparently there are no records of the genus from the tropical eastern Pacific, beyond those from Cedros Island and Peru, the northern and southern boundaries respectively, of our region.

Family SPHYRNIDAE.

Sphyrna Rafinesque, 1810.

Hammerhead and Shovelhead Sharks.

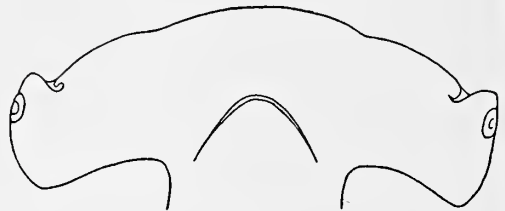
Key to tropical eastern Pacific species.²⁴

- 1a. Second dorsal fin with a long posterior lobe, which when lifted upward, will reach about twice as high as the fin; anterior margin of the head three-lobed. *zygaena*
- 1b. Second dorsal fin with a short posterior lobe, which when lifted upward, will reach about as high as the fin.
- 2a. Front margin of the head between the nasal apertures lobed, the front margin not forming a continuous curve.

- 3a. Head hammer-shaped; oculo-narial expanse irregularly quadrangular, almost exactly transverse in old adults; teeth heavy, serrate. *tudes*
- 3b. Head not definitely hammer-shaped; oculo-narial space irregularly oval; teeth slender, not serrate. *corona*
- 2b. Front margin of the head between the nasal apertures not lobed, the front margin forming a continuous curve.
 - 4a. Teeth with low cusps, the cusps progressively smaller towards the angles of the jaws, entirely absent on one or two rows in the upper jaw and on four or five rows in the lower jaw; head broadly spade-shaped; length of snout to mouth 1.5 to 1.75 in the internal distance. *vespertina*
 - 4b. All teeth with cusps; oculo-narial space broadly oval; length of snout to mouth 2.2 in internal distance. *media*

Sphyrna zygaena (Linnaeus).

Cruz, Pez Martillo.



Text-figure 24.

Range: Tropical and temperate seas; known in the eastern tropical Pacific from southern California, Mexico, Panama, Peru and the Galápagos Islands. (Mexico: San Lucas Bay, Mazatlan, Guaymas; Panama: Panama; Peru: Lobos de Tierra, Callao; Galápagos Islands).

Field Characters: A large shark with head expanded laterally, hammer-shaped; anterior edge of head between nostrils three-lobed; a line connecting the centers of the eyes passes through the mouth; diameter of eye greater than anterior extension of head immediately in front of eye; posterior lobe of second dorsal fin, when lifted upward, reaches twice as high as the fin. (Illustration from specimen 25,549; 1,030 mm.)

Size: Grows to 17 to 20 feet and a weight of 1,500 pounds.

Study Material: 1 specimen. Mexico: San Lucas Bay, Lower California, 1 (25,549), 1,030 mm., May 5, 1936, harpooned.

References: *Squalus zygaena*, Linnaeus, *Syst. Nat.*, ed. X, 1758: 234 (original description; Europe, America).

Sphyrna zygaena, Jordan, D. S. & Gilbert, C. H., *Bull. U. S. Fish Comm.*, 2, 1882: 105 (Mazatlan). Jordan, D. S., & Gilbert, C. H., *Bull. U. S. Fish Comm.*, 2, 1882: 109 (Panama). Evermann, B. W., & Jenkins, O. P., *Proc. U. S. Nat. Mus.*, 14, 1891 (1892): 131 (2½ foot specimen from Guaymas, Mexico). Jordan, D. S., *Fishes of*

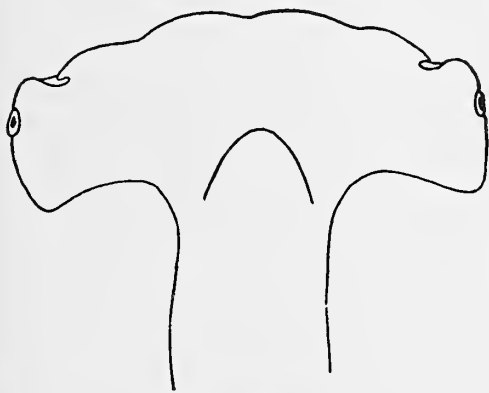
¹⁹ Evermann & Radcliffe, *U. S. Nat. Mus., Bull.* 95: 1917: 10.
²⁰ Fowler, *Proc. 4th Pac. Sci. Congr.* Java 1929, 3, 1930: 490.
²¹ Philippi, *Ann. Univers. Chile*, 71, 1887: 543, Plate 4, fig. 2.
²² Perez, *Estudios sobre algunos escualos de la costa de Chile*, 1886: 3.
²³ Fowler, l. c., 490.
²⁴ Adapted with slight modifications from Springer (1940). *Sphyrna peruana* Phillipi from Chile and Peru has not been considered here. The amount of material in our collection of *zygaena* and *tudes* is so small that we have made no attempt to determine whether the eastern Pacific species should be considered as local races, as seems to be indicated in many of the littoral tropical eastern Pacific sharks.

Sinaloa, 1895: 383 (Mazatlan). Jordan, D. S., & Evermann, B. W., *Fishes of North and Middle America*, 3, 1898: 2748 (Mazatlan). Pellegrin, J., *Bull. Mus. Hist. Nat., Paris*, 7, 1901: 161 (Gulf of California). Gilbert, C. H., & Starks, E. C., *Fishes of Panama Bay*, 1904: 13 (abundance in Panama Bay), 207 (range). Starks, E. C., *Proc. U. S. Nat. Mus.*, 30, 1906: 762 (eastern Pacific range), 763 (Callao, Peru). Garman, S., *Bull. Mus. Comp. Zool.*, 46 (12), 1906: 229 (Panama). Hussakof, L., *Copeia*, 34, 1916: 63-64 (comparison of Atlantic and Pacific hammerheads, development of teeth). Evermann, B. W., & Radcliffe, L., *Bull. U. S. Nat. Mus.*, 95, 1917: 5 (Lobos de Tierra, Peru; measurements of a 1,000 mm. shark, short synonymy, questioning relationship of *S. peruana* Philippi). Nichols, J. T., & Murphy, R. C., *Bull. Amer. Mus. Nat. Hist.*, 46, 1922: 504 (Lobos de Tierra, Peru). Walford, L. A., *Fish and Game of California*, *Bull.* 45, 1935: 40, fig. 38 (figure, notes). Walford, L. A., *California Fish and Game*, 17, 1931: 404 (off southern California coast, landed at San Pedro and Santa Monica). Clark, H. W., *Proc. Cal. Acad. Sci.*, (4) 21 (29) 1936: 395 (Galápagos Islands, pile of dried skins). Walford, L. A., *Marine Game Fish of the Pacific Coast*, 1937: plate 25 (figure). Seale, A., *Allan Hancock Pacific Expeditions*, 9 (1), 1940: 2 (Galápagos Islands; abundance).

Cestracion zygaena, Garman, S., *The Plagiostomia*, 1913: 157, plate 1, fig. 1-3 (Synonymy, des. of Atlantic specimen, figure).

Discussion: Our specimen from San Lucas Bay agrees well with illustrations of specimens recorded as *zygaena* from the Atlantic and other localities.

Sphyrna tudes Valenciennes.



Text-figure 25.

Range: Tropical seas. (All of the definite records within the coastal tropical eastern Pacific area, are concentrated in the Gulf of California: Concepcion Bay, Arena Bank, San Francisquito Bay, Guaymas.)

Field Characters: A large shark with head

expanded laterally, hammer-shaped; anterior border of head between the nostrils four-lobed; a line joining the centers of the eyes passes in front of the mouth; diameter of eye equal to anterior extension of head immediately in front of eye; posterior lobe of second dorsal fin, when lifted upward, reaching about as high as the fin. (Illustration from specimen No. 25247; 1,334 mm.).

Size and Weight: Grows to about 5 feet.

Study Material: 2 specimens. Mexico: Concepcion Bay, Lower California, 1 (25,247), 1,334 mm., April 16, 1936 (head and pectoral fins preserved). Arena Bank, Lower California, 1 (25,485), May 1, 1936, dried head picked up on beach, 767 mm. across the "hammer."

References: *Sphyrna tudes*, Valenciennes, A., *Mem. Mus. Hist. Nat. Paris*, 9, 1822: 225, Pl. 12, fig. 1 (original description, figure). Evermann, B. W., & Jenkins, O. P., *Proc. U. S. Nat. Mus.*, 14, 1891 (1892): 131 (Guaymas; synonymy wrong). Pellegrin, J., *Bull. Mus. Hist. Nat. Paris*, 7, 1901: 161 (name only, Gulf of California), 166 (abundance). Breder, C. M., Jr., *Bull. Bingham Oceanogr. Coll.*, 2 (1) 1928: 4 (San Francisquito Bay, Gulf of California).

Discussion: The two fish at hand constitute too small a sample for adequate comparison with specimens of *tudes* from other localities. The large head agrees in shape and form with the head of the smaller example and there is no doubt that the two heads represent the same species. They both agree well with descriptions of *tudes* from other localities. The teeth of the large fish are lost; those of the 1,334 mm. shark are non-serrated.

This species, although supposedly wide spread in tropical seas, seems to be known in the eastern tropical Pacific only from the Gulf of California. Springer (1940) has shown that some of the older records within our faunal area that were assigned to *tudes* belong to new species described by him.

The Galápagos Islands record of *tudes*²⁵ of Snodgrass & Heller, is inconclusive and may refer to some of Springer's species.

Sphyrna corona Springer.

Range: Panama (Panama City) and "west coast of Mexico."

Field Characters: Medium sized sharks with head expanded laterally, kidney-shaped; front of head lobed, the posterior border of the head not parallel to the anterior border. (Illustration after Springer, 1940).

Size: Grows to about three feet.

Study Material: None.

References: *Sphyrna corona*, Springer, S., *Stanford Ichthy. Bull.*, 1 (5) 1940: 163, fig. 4 (original

²⁵ Snodgrass, R. E., & Heller, E., *Proc. Wash. Acad. Sci.*, 6, 1905: 345.



Text-figure 26.

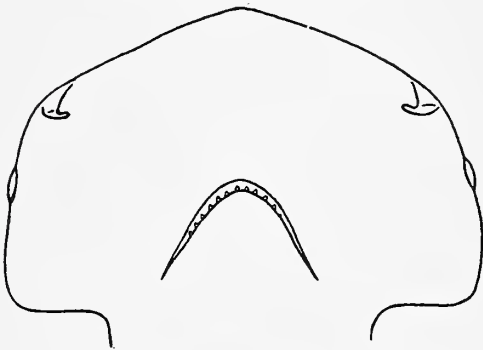
description, figure; type-locality Panama; type, No. 11,882, Stanford University).

Sphyrna tudes, Jordan, D. S., & Evermann, B. W., Fishes of North and Middle America, 1, 1896: 44 (in part).

Sphyrna tiburo, Kumada, T., & Hiyama, Y., Marine Fishes of the Pacific Coast of Mexico, 1937: 17, plate 1 (figure and short comment).

Discussion: Judging by head shape, the approximately 915 mm. shark figured by Kumada & Hiyama (*l. c.*) under the name of *Sphyrna tiburo*, is the same as *corona*.

Sphyrna vespertina Springer.



Text-figure 27.

Range: Panama and Ecuador.

Field Characters: A small shark with expanded spade-shaped head, the front margin of the head between the nostrils not lobed, the head slightly pointed anteriorly; teeth with low cusps, the cusps becoming progressively smaller toward the angles of the jaws, entirely absent on one or two rows in the upper jaw and on 4 to 5 rows in the lower jaw. (Illustration after Springer, 1940.)

Size: Grows to about three feet.

Study Material: None.

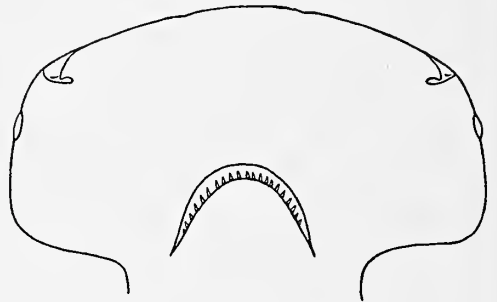
References: *Sphyrna vespertina*, Springer, S., *Stanford Ichthy. Bull.*, 1 (5), 1940: 161, fig. 2 (original description, figure; type-locality, Panama; type, No. 11,584, Stanford University).

Sphyrna tiburo, Gilbert, C. H., & Starks, E. C., Fishes of Panama Bay, 1904: 13 (Discussion of so-called *tiburo* and *tudes*). Wilson, C., *Ann. Carn. Mus. Pitts.*, 10, 1916: 58 (Guayaquil, Ecuador).

Discussion: Probably most of the eastern Pacific records of *tiburo* will be found to refer to this species. Springer in his 1940 paper infers that *tiburo* is Atlantic only, as he states of *vespertina* ". . . It is closely allied to *Sphyrna tiburo* of the Caribbean, Gulf of Mexico and the Atlantic coast of the Americas. . ."

The reference to *tiburo* of Kumada in "Marine Fishes of the Pacific Coast of Mexico," 1937: Plate 1, has been placed under *Sphyrna corona*. Specimens mentioned in the following references require study: Meek, S. E., & Hildebrand, S. F., Marine Fishes of Panama, 1, 1923: 60-61 (Panama); Starks, E. C., *Proc. U. S. Nat. Mus.*, 30, 1916: 762 (range), 763 (specimen from Guayaquil, Ecuador), and Jordan, D. S., Fishes of Sinaloa, 1895: 383 (one specimen from Mazatlan).

Sphyrna media Springer.



Text-figure 28.

Range: Mexico and Panama. (Mexico: Mazatlan; Panama: Panama market.)

Field Characters: Medium-sized sharks with head expanded laterally, the anterior margin between the nostrils in a continuous curve, not lobed; all teeth with cusps.

Study Material: None.

References: *Sphyrna media*, Springer, S., *Stanford Ichthyological Bull.*, 1 (5), 1940: 162, fig. 3 (original description, figure; type-locality, Mazatlan, Mexico; type, No. 11,583, Stanford University).

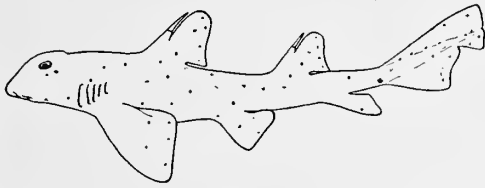
Sphyrna tudes, Jordan, D. S., Fishes of Sinaloa, 1895: 383 (Mazatlan, Mexico). Jordan, D. S., & Evermann, B. W., Fishes North and Middle America, 1, 1896: 44 (in part). Gilbert, C. H., & Starks, E. C., Fishes of Panama Bay, 1904: 13, (Panama market).

Family HETERODONTIDAE.

Heterodontus Blainville, 1816.

Key to tropical eastern Pacific species.

- 1a. Origin of first dorsal fin over the base of the pectoral fins; distance from snout to origin of first dorsal fin 28 to 30% of the length; black spots on body separate and widely spaced, rarely merged together. *francisci*
- 1b. Origin of first dorsal fin behind the base of the pectoral fins; distance from snout to origin of first dorsal fin 32 to 37% of the length; black spots on body larger, three or four joining together to form larger spots or bands. *quoyi*

Heterodontus francisci (Girard).

Text-figure 29.

Range: Southern California, Lower California, Gulf of California. Recorded south of San Diego, California, from the following localities, Mexico: Todos Santos Bay, Magdalena Bay, Angel de la Guardia Island, Concepcion Bay and San Francisquito Bay.

Field Characters: Small robust sharks with eyes beneath heavy suborbital ridges and with a spine in front of each dorsal fin; spiracle present below posterior part of eye; origin of first dorsal fin over the base of the pectoral fin; upper surfaces of the body with black subcircular spots which are separate and detached from each other, rarely close together or merging. (Illustration after Kumada and Hiyama, 1937: 532 mm.)

Size: Grows to three feet.

Study Materials: No specimens were obtained by the Zoological Society's expeditions. We have examined fishes from Concepcion Bay, San Francisquito Bay and Angel de la Guardia Island, Gulf of California.

References: *Cestracion francisci*, Girard, C. F., *Proc. Acad. Nat. Sci. Phila.*, 7, 1854: 196 (original description; type locality: Monterey Bay, California).

Heterodontus francisci, Smith, R., *Proc. U. S. Nat. Mus.*, 6, 1883 (1884): 233 (Egg-cases on beach, Todos Santos Bay, Mexico). Pellegrin, J., *Bull. Mus. Hist. Nat. Paris*, 7, 1901: 161. (Gulf of California.)

Gyropleurodus francisci, Osburn, R. C., & Nichols, J. T., *Bull. Amer. Mus. Nat. Hist.*, 35, 1916: 141 (8' specimen dredged in 13 fathoms, Magdalena Bay, Mexico). Breder, C. M., Jr.,

Bull. Bingham Oceanogr. Coll., 2 (1), 1928: 3 (Concepcion Bay and San Francisquito Bay, Gulf of California). Kumada, T., & Hiyama, Y., *Marine Fishes West Coast of Mexico*, 1937: 15, Plates 44, 45 (figure).

Heterodontus quoyi (Fremenville).

Range: Peru (Lobos de Tierra and Lobos de Afuera Islands); Galápagos Islands. An indefinite record from the west coast of Mexico, and a possible egg-case of this species from San Elena Bay, Ecuador.

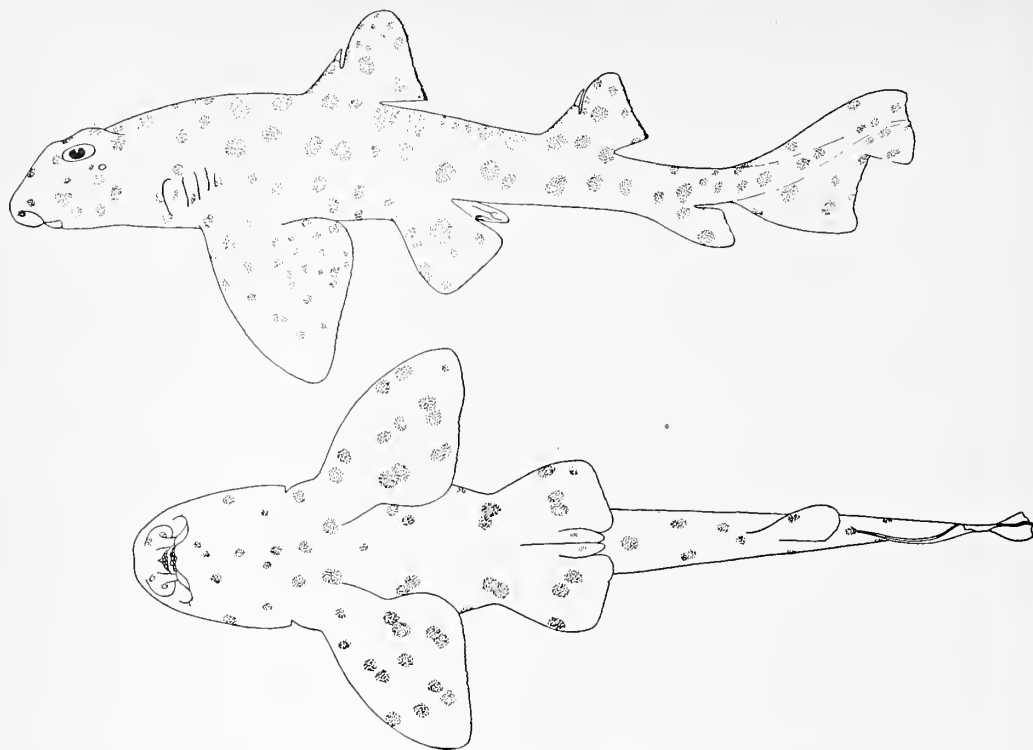
Field Characters: Small, robust sharks with eyes beneath heavy supraorbital ridges and with a short spine in front of each dorsal fin; spiracle present, beneath posterior part of eye; origin of first dorsal fin behind the vertical of the base of the pectoral. Brownish to grayish, the upper and lower surfaces of body with black spots which merge to form larger spots and bands. (Illustration from specimen No. 6161: 375 mm.)

Size: Grows to at least eighteen inches.

Description: Our Galápagos Island specimen is described as follows, the proportions being expressed in percentages of the total length, which is 375 mm.:

Body robust, tapering posteriorly; snout to 1st gill-slit 18%, snout to fifth gill-slit 23.7; snout to eye 9.2, horizontal diameter of eye 3.3; a strong supra-orbital ridge ending less than an eye's diameter back of the eye, the ridges anterior to the eye converge at first and then become parallel and less evident on the snout. Snout to first dorsal fin 34, the fin originating about 2.6 back of the vertical of the posterior part of the pectoral base; base of first dorsal fin 8.25, anterior edge 13.6, base to tip of posterior lobe 5.1, vertical height of fin from body 10.4, the fin rounded above, its free edge slightly concave and with no posterior extension. Origin of first dorsal to tip of spine 6.7, vertical height of spine from body 5.85. Interdorsal space 17. Snout to second dorsal fin 54, the fin similar in shape but slightly smaller than the first dorsal fin. Caudal fin length 22, the fin with a large terminal lobe and a large inferior lobe, the length of the latter being 13.3. Snout to pectoral fin 19, the fin low, large and horizontal; pectoral base 8.8, anterior border 21.4, inner border 7.2, free border 16, greatest breadth 14.4. Snout to pelvic fin 42.7, the fin originating slightly posterior to the vertical of the posterior base of the first dorsal fin, pelvic fin base 7.85, anterior border 10.7, inner border 8.5; the claspers do not reach the inner tip of the fin. Snout to anal fin 68, the fin originating under the posterior tip of the second dorsal fin, the tip of the anal reaching to the base of the caudal, base of anal 5.5, anterior border 9.9, inner border 3.3. Height of first gill-slit 4, height of 5th gill-slit 2.27, the posterior three slits above the pectoral fin. Spiracle small, beneath and posterior to the eye.

Teeth similar to those mentioned in Garman's account (1913) and figure, except that the an-



Text-figure 30.

terior teeth have five rather dull cusps. The teeth in the Peruvian example that we have studied are much sharper and tricuspid, so that in this species as well as in *francisci*, there is an evident reduction with age in the number of cusps on the anterior teeth.

Denticles from the side immediately beneath the first dorsal fin are X-shaped with one of the arms of the X stronger and heavier toward its outer extremities. Denticles from the posterior part of the body have the spaces between the arms of the X filled in and the denticles are roughly rhomboidal in shape.

Color: Immediately after being taken from the stomach of a shark, above neutral gray, below and on sides dotted with large round black spots.

Size and Weight: Our 375 mm. fish weighed 456 grams (1 pound).

Enemies: The *Arcturus* specimen was taken from the stomach of a seven-foot tiger-shark (*Galeocerdo arcticus*).

Egg Case: See under *Discussion*.

Study Materials: 2 specimens. Galápagos Islands: Albemarle Is., 1, male (6161), 375 mm., June 9, 1925 (*Arcturus* Expedition), stomach of tiger-shark. Peru: Lobos de Afuera Island, 1 female (Amer. Mus. Nat. Hist. 7489) washed ashore dying.

References: *Cestracion quoyi*, Freminville, C. P., *Mag. de Zool.*, (2) 2, 1840: pl. 3 (description, figure; type-locality: Galápagos Islands). Gün-

ther, A., *Cat. Fishes Brit. Mus.*, 8, 1870: 416 (short description, synonymy).

Cestracion pantherinus, Valenciennes, A., Voyage "Venus," *Zoology*, 1845: 350, pl. 10, fig. 2 (description, excellent figure, Galápagos Islands).

Tropidopus pantherinus, Gill, T. N., *Proc. Acad. Nat. Sci. Phila.*, 1862: 489, 490 (new genus established for this species).

Heterodontus (Cestracion) quoyi, Dumeril, A. H. A., *Hist. Nat. Poiss.*, 1, 1865: 427; atlas, pl. 3, fig. 16, 17 (description, color, figure of teeth).

Heterodontus quoyi, Miklukho-Maklai, N. N., & Macleay, W., *Proc. Linn. Soc. N. S. Wales*, 3, 1878: 316, pl. 26, fig. 35 (comments, no specimens, copy of original plate of Freminville). Fowler, H. W., *Proc. 4th Pac. Sci. Congress*, Java 1929, 3, 1930: 484 (check-list only, Galápagos Islands).

Gyropleurodus quoyi, Jordan, D. S., & Evermann, B. W., *Fishes North and Middle America*, 1, 1896: 21 (poor description, synonymy), Regan, C. T., *Ann. Mag. Nat. Hist.* (8) 1: 494.

Cestracion quoyi, Garman, S., *The Plagiostomia*, 1913: 187, pl. 47, fig. 1-3 (description, synonymy, figure of teeth).

Gyropleurodus peruanus, Evermann, B. W., & Radcliffe, L., *Bull. U. S. Nat. Mus.*, 95, 1917: 2, pl. 1, fig. 1 (description, figure; type-locality: Lobos de Tierra Island, Peru). Nichols, J. T., & Murphy, R. C., *Bull. Amer. Mus. Nat. Hist.*, 46, 1922: 504 (Lobos de Afuera, Peru; specimen

washed ashore in dying condition). ? Kumada, T., & Hiyama, Y., *Marine Fishes of the Pacific Coast of Mexico*, 1937: 16, pl. 46 (west coast of Mexico; figure), see comment under *Discussion*.

Heterodontus peruanus, Fowler, H. W., *Proc. 4th Pac. Sci. Congr., Java* 1929, 1930: 484 (check-list; Peru).

Discussion: Two species of *Heterodontus* have been reported from the equatorial eastern Pacific, *quoyi* from the Galápagos Islands and *peruanus* from the coast of Peru.

The original description of *quoyi* (Freminville, 1840) is very poor and the figure that illustrates the description is crude. The plate shows a fish with an exceedingly small pectoral fin, an anal fin with its origin beneath the tip of the posterior extension of the second dorsal fin and with very large, irregularly-formed dark spots.

Valenciennes, in 1855, redescribed the Galápagos fish under the name *Cestracion pantherinum*, giving an excellent figure with details of anatomy and color that agree well with our recent Galápagos material.

Garman (1913) described an 18-inch female of *quoyi* from the Galápagos Islands and gave splendid figures of the teeth. Unfortunately, we have been unable to find the specimen or specimens upon which his description was based.

Evermann & Radcliffe first described and figured the South American coastal form, *peruanus*, the type being a 565 mm. fish from Lobos de Tierra, Peru.

For purposes of comparing *quoyi* and *peruanus*, we have, in addition to the descriptions mentioned above, two topotypical specimens, a 375 mm. fish from Tagus Cove, Albemarle Island, Galápagos Islands, and a 523 mm. fish (Amer. Mus. Nat. Hist. 7489) previously recorded by Nichols & Murphy from Lobos de Afuera, Peru, some 20 miles from the type locality of *peruanus*. The latter specimen agrees completely with the original description and figure of *peruanus*.

As these fish are of different sizes, there is a slight question as to their identity. Consequently it is necessary to take up the discussion in some detail, although there is no doubt in our minds that they belong to the same species.

When Evermann & Radcliffe described *peruanus*, they stated: "This species appears to be most closely related to the poorly described *quoyi*, but differs in coloration, in insertion of the anal and relative size of the pectoral."

However, when the two specimens at hand, representing topotypical examples of both *quoyi* and *peruanus*, are compared, we find that the relative sizes of the pectoral fins are exactly the same (the proportional measurements are identical), and that the insertion of the anal fin is in the same relative position in the two fishes. This leaves only the color as supposedly different.

As our Galápagos Island shark is smaller than the two known Peruvian fishes and as it was taken from the stomach of a tiger-shark, its color cannot be depended upon for direct com-

parisons. The general pattern, where observable, consists of large diffuse dark spots similar to those of the Peruvian shark, and in this, it agrees with Valenciennes' figure of a Galápagos fish illustrated in the "Voyage of the Venus."

In the original description of the Peruvian form, conspicuous black bands on the dorsal surface are recorded. In Garman's description of a similar sized Galápagos specimen the same pattern is mentioned. However, in the American Museum Peruvian fish, in our Galápagos Island specimen and in Valenciennes' plate there is no indication of these bands. Evidently their presence or absence is variable. Under any circumstances, it is obvious that the difference in pattern cannot be assigned to a geographical range.

Thus we find that the coloration and pattern in the two nominal forms are the same, and as there are thus no distinguishing characters left between the coastal and the South American mainland form, we consider them as identical.

All of the known Galápagos and Peruvian specimens of *Heterodontus* have relatively low and robust dorsal spines. The northern species, *francisci*, has much longer and slimmer spines. This distinction is most marked in smaller specimens, but it also holds true when comparisons are made with equal-sized larger specimens.

The specimen illustrated by Kumada & Hiyama (*Marine Fishes of the Pacific Coast of Mexico*, 1937: 16, Plate 46) introduces an uncertain note into the discussion of the American species of *Heterodontus*. This fish was found far north of the range of *quoyi* as previously recorded and within or near the range of *francisci*. Kumada & Hiyama's plate, which was based upon a photograph, shows a fish with the dorsal fin insertion like that of *francisci*, while the shape and size of the dorsal fins is that of *quoyi*. The color pattern is intermediate between the two forms, the spots being larger than in *francisci* and more isolated and separated than is the case in *quoyi*. The general appearance, however, is predominantly *quoyi*-like. For the present, we assume that this fish was correctly assigned to *peruanus*, and that the differences are merely variations from our present conception of the species. The exact locality from which the Kumada & Hiyama shark was taken is unknown—somewhere along the west coast of Mexico.

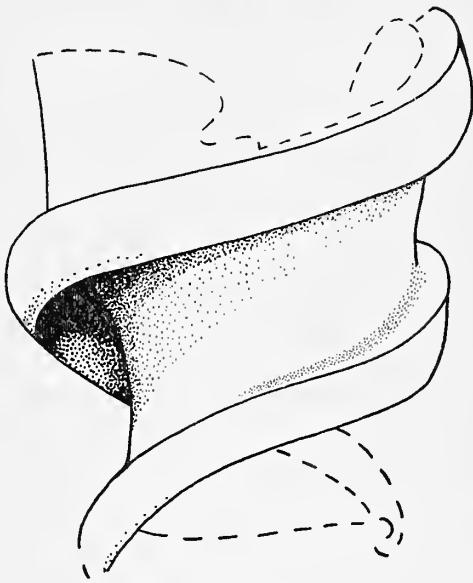
An egg-case of a heterodontid shark dredged by us at Station 136:D-16, Arena Bank, Gulf of California, April 20, 1936, in 45 fathoms, amply validates the existence of a second species of bull-head shark in the northern part of the tropical eastern Pacific in addition to *francisci*. This egg-case probably belongs to the present species as exemplified by Kumada & Hiyama's specimen.

The egg-case of *Heterodontus francisci* is well known, and has been figured by Daniels²⁶ and Barnhart;²⁷ it is screw-shaped with characteristic

²⁶ Daniels, J. F., *The Elasmobranch Fishes*, 1922: 318.

²⁷ Barnhart, P. S., *Bull. Scripps Inst. Oceanogr. Tech. ser.*, 3 (4) 1932: 88.

flanges and lacks tentacles. Our specimen is quite different and resembles in general form and the possession of long tentacles, the egg-case of *Heterodontus galeatus* as illustrated by Waite.²⁸



Text-figure 31.

When first secured our egg-case was broken at the top (considering the smaller tentacled end as the bottom, as shown in Waite's figure²⁸ and since then it has become even more fractured and fragmentary. However, even from this material it is evident that this egg-case can be distinguished from that of *galeatus* by the fact that the spiral flanges have their outer border vertical; i. e., more or less parallel to the long axis of the egg-case and that the upper aspect of the flange is a flat ledge at a right angle with the body of the egg-case. In Waite's illustration of the *galeatus* egg-case, these flanges are oblique to the vertical axis, more or less continuing the general direction of the body of the egg-case.

The width across the widest portion of the egg-case is approximately 44 mm., the width of one of the flanges at about the middle of the egg-case is 7.5 mm.

Tortonese²⁹ reports a somewhat similar egg from Ecuador under the name of *Heterodontus* sp., although we do not understand his reference to four appendages. This must certainly belong to *quoyi*; it was 64 mm. long.

²⁸ Waite, E., *Journ. Linn. Soc. Zool. Lond.*, 25, 1896: Plate 12, and "The Fishes of Australia," Part 1, Sharks, etc., 1940: 38.

²⁹ Tortonese, E., *Boll. Musei Zool. Anat. Comp. Torino*, (3) 47, no. 89, 1939: 2.

Family SQUALIDAE.

Centroscyllium Müller & Henle, 1838.*Centroscyllium nigrum* Garman.

Text-figure 32.

Range: Offshore Panamic region in 546 to 625 fathoms; taken 15 miles west of Mariato Point, Panama, 65 miles south-west of Mariato Point, Panama, and 60 miles south of Cocos Island, Offshore, Kauai Island, Hawaiian Islands in 385 to 500 fathoms.

Field Characters: Very small, large-eyed sharks with well-developed spiracle and with a spine before each dorsal fin; anal fin lacking. Black with white outer borders to the dorsal, pectoral and ventral fins. (Illustration from specimen No. 6013; 278 mm.)

Color: Black with white dorsal spines and posterior borders to the dorsals, pectorals and pelvic fins; eye emerald green.

Size: Grows to about a foot in length.

Food: Our specimens had fed upon scarlet prawns.

Study Material: 8 specimens. Station 74:OT-4, *Arcturus* Oceanographic Expedition, 4° 50' N., 87° 00' W., 60 miles south of Cocos Island, 625 fathoms (1,145 meters), 125 to 278 mm. long, May 30, 1925, otter trawl. Cat. Nos. 6013, 6014a, b, c, d, e, f, g.

References: *Centroscyllium nigrum*, Garman, S., *Mem. Mus. Comp. Zool.*, 24, 1899: 28, Plate 1, fig. 2, Plates 4 and 5, Plate 69, fig. 1 (original description, skull and skeletal characters, heart, skin, sensory system, color; figure, figures of head, skull, teeth, denticles, branchial cartilages, intestine, shoulder and pelvic girdles and lateral line systems; type locality: Pacific Ocean, between 6° and 7° N. Lat., and 81° and 82° W. Long., in depths of 546 to 555 fathoms). Garman, S., *The Plagiostomia*, 1913: 231 (synonymy, description). Beebe, W., "The *Arcturus* Adventure," G. P. Putnam's Sons, New York, 1926: 359 and 436 (color and food).

Centroscyllium ruscusum, Gilbert, C. H., *Bull. U. S. Fish Comm.*, 23, 1905: 580, fig. 230 (description, figure, color).

Discussion: Garman³⁰ states of this species: "One of the more prominent differential characters of the species described below, *C. nigrum*, is apparent in the five cusped teeth, the teeth of each of the other species being described as *tricuspid*. . . ." However, the specimens at

³⁰ Garman, *Mem. Mus. Comp. Zool.*, 24, 1899: 27.

hand from close to the type-locality and from the same depths as the type of *C. nigrum*, demonstrate considerable variation from this description. Thus the lower jaw teeth possess, for the most part, but three cusps with indications of a single additional cusp on each side, making five in all as in the original description of the species. However, these additional cusps are very small and never as prominent as shown in the original figures of the species. Without careful observation they might easily be missed. They can most easily be seen when the teeth are dried and viewed with transmitted light.

In the description of the cotype of the nominal *ruscosum*, Gilbert found the same condition.

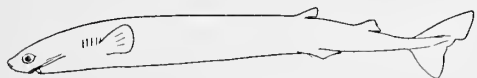
Squalus Linnaeus, 1758.

Gunther's questionable Panama record of *Acanthias vulgaris*³¹ cannot be referred to any definite known species, and it also may have come from the Atlantic. Comments on this record have been made by Gilbert & Starks,³² and Meek & Hildebrand.³³ Beyond this note the genus is unrecorded from the eastern tropical Pacific, although *Squalus suckleyi* is known from immediately north of the region and is also reported from Chile, while *Squalus lebruni* and *S. fernandinus* are known from south of the region.

Family SCYMNORHINIDAE.

Isistius Gill, 1864.

Isistius brasiliensis (Quoy & Gaimard).



Text-figure 33.

Range: Known from many localities in tropical and temperate seas; in the eastern tropical Pacific known from Hawaii and in our region from a single specimen taken in open ocean 150 miles north of the Galápagos Islands. Taken principally near the surface, doubtfully recorded from great depths.

Field Characters: Small, large-eyed sharks with very small dorsal fins placed far back on the body, no anal fin, a dermal keel on each side of the tail, a short deep caudal fin. Brown, with a darker band around the neck across the gill-openings; lower surfaces lighter to white. (Illustration after Garman, 1899; 460 mm.)

³¹ Gunther, A., *Trans. Zool. Soc. London*, 7, 1868: 396.

³² Gilbert, C. H., & Starks, E. C., *Fishes of Panama Bay*, 1904: 13.

³³ Meek, S. E., & Hildebrand, S. F., *Marine Fishes of Panama*, 1, 1923: 64.

Size: Grows to 19½ inches in length.

Study Material: None.

References: *Scymnus brasiliensis*, Quoy, J. R. C., & Gaimard, P., in Freycinet, L. de, *Voyage autour du monde pendant 1817-1820, 1824*: 198 (type locality: off Brazil).

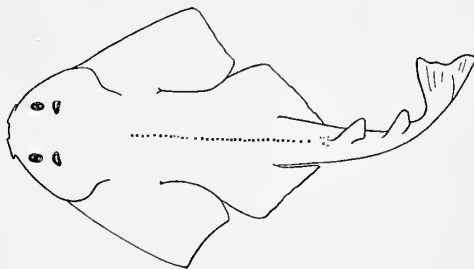
Isistius brasiliensis, Garman, S., *Mem. Mus. Comp. Zool.*, 24, 1899: 34, Plate 1, fig. 1, Plate 2 and 3, Plate 49, fig. 2 (synonymy, description, skull, skeleton, internal organs, lateral line system, coloration, phosphorescence, historical notes; 1 specimen 18 inches long, taken 153 miles N by W of Albemarle Island, Galápagos Islands, in beam trawl).

Family SQUATINIDAE.

Squatina Dumeril, 1806.

Squatina californica Ayres.

Angel Shark.



Text-figure 34.

Range: South-eastern Alaska to San Diego with two indefinite records from Mexico, and questioned records from Peru and Chile.

Field Characters: A flattened ray-like shark with gill openings on the sides in a space between the head and the expanded pectoral fins; ventral fins expanded. Dark brownish or ashy, almost black, or reddish-brown above; white below.

Size: Attains a length of five feet and a weight of 60 pounds.

Study Material: None.

References: *Squatina californica*, Ayres, W. O., *Proc. Cal. Acad. Sci.*, 1859; 29; *ibid.*, 1860: fig. 7 (original description, outline figures; type locality, San Francisco). Garman, S., *The Plagiostomia*, 1913: 253, plate 16, figs. 1-4, plate 61, figs. 9-11 (description, figures; range: California and Mexico). Kumada, T., & Hiyama, Y., *Marine Fishes of the Pacific Coast of Mexico*, 1937: 17, plate 49 (plate and brief diagnosis of a specimen from somewhere along the west coast of Mexico).

Squatina squatina, ? Evermann, B. W., & Radcliffe, L., *U. S. Nat. Mus., Bull.* 95, 1917: 11 (dimensions, short description, color; Lobos de Tierra, Peru). ? Pellegrin, J., *Bull. Soc. Zool. Paris*, 29, 1904 (Chile).

Discussion: The status of specimens of the genus *Squatina* from localities in the eastern Pacific is by no means clear. Thus there exists a tendency to amalgamate the European, the western Atlantic and eastern Pacific angel-sharks under the all-inclusive name *Squatina squatina* (Linnaeus). In keeping with this, *S. californicus* Ayres, described from California, has been synonymized with *S. squatina*, and specimens from Peru and Chile have also been reported under the same name.

Whether the angel-sharks from northern and southern localities in the eastern Pacific represent the same species and whether they should be considered as the same as the European *squatina*, is a question. Our assumption, based on observations of other littoral sharks of the region, is that the eastern fish are not the same as the Atlantic or European form, and that a northern and southern species of the eastern Pacific fish could probably be differentiated. Thus we are uncertain as to the status of the 560 mm. fish recorded from Lobos de Tierra by Evermann & Radcliffe³⁴ and the fish recorded by Pellegrin from Chile.³⁵ Norman³⁶ suggests that the former record may refer to *S. armata* (Philippi).

Two additional species of *Squatina* have been recorded from the west coast of South America: *S. armata* Philippi³⁷ described from Iquique, Chile, and redescribed by Norman³⁸ from an Argentine specimen with a question as to its identity, and *S. philippi* Garman³⁹ from Mxil-lones, Chile.

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- GILBERT, C. H. & STARKS, E. C.
The Fishes of Panama Bay, *Mem. Calif. Acad. Sci.*, 4, 1904: 1-304, Plates 1-33.
- JORDAN, D. S.
The Fishes of Sinaloa, *Proc. Cal. Acad. Sci.*, (2), 5, 1895: 377-514 (Separate pagination 1-142), Plates 26-55.

³⁴ Evermann, B. W., & Radcliffe, L., *U. S. Nat. Mus.*, *Bull.* 95, 1917: 11.

³⁵ Pellegrin, J., *Bull. Soc. Zool. Paris*, 29, 1904:

³⁶ Norman, J. R., *Discovery Reports*, 16, 1937: 10, 11.

³⁷ Philippi, R. A., *Ann. Univ. Chile*, 71, 1887: 561, pl.

7, fig. 1.

³⁸ Norman, J. R., *Discovery Reports*, 15, 1937: 10.

³⁹ Garman, S., *The Plagiostomia*, 1913: 254.

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The Marine Fishes of Panama, *Field Mus. Nat. Hist., Zool. Ser.*, 15, 1923: xi, 1-330, Plates 1-24.

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A Check List of the Fishes of southern California and Lower California. *Journ. Pan-Pac. Res. Inst.*, 4 (4), 1929: 2-11.

PLATE I.

- Fig. 1. *Rhineodon typus*. 42-foot specimen from Arena Bank, Lower California.
- Fig. 2. *Rhineodon typus*. Whale shark photographed from motor boat while swimming close to surface, Gorda Banks, Lower California. View of part of head, body, gill-slits and pectoral fin. Two remoras are on the base of the pectoral fin.

PLATE II.

- Fig. 1. *Trienodon obesus*. Specimen from Bahia Honda, Panama, 1,175 mm. total length.
- Fig. 2. *Eulamia aethalorus*. Embryo, 650 mm., taken from 2,070 mm. adult, Arena Bank, Lower California.
- Fig. 3. *Eulamia velox*. Specimen from San Lucas Bay, Lower California, 945 mm. total length.



FIG. 1.



FIG. 2.

FISHES OF THE TROPICAL EASTERN PACIFIC.
PART 2. SHARKS.

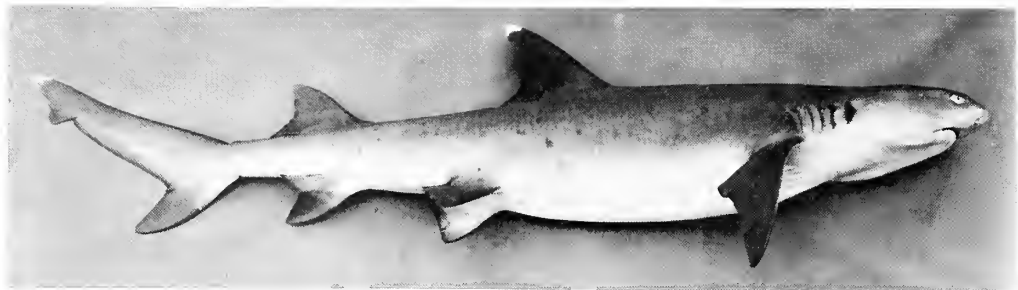


FIG. 1.



FIG. 2.

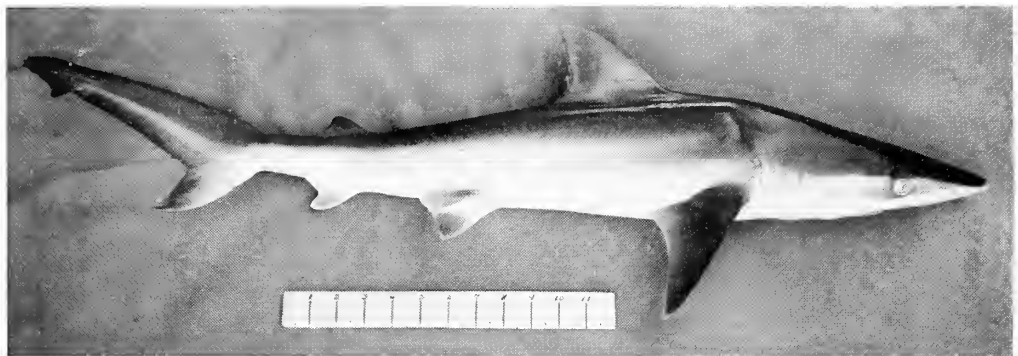


FIG. 3.

FISHES OF THE TROPICAL EASTERN PACIFIC.
PART 2. SHARKS.

16.

Correlations Between Structural Eye Defects and Behavior in the Mexican Blind Characin.

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&

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New York University College of Medicine (Department of Ophthalmology).

(Plates I-IV; Text-figures 1 & 2).

INTRODUCTION.

Hubbs & Innes (1936) reported the discovery of a new species of blind cave fish inhabiting the warm water caves in the vicinity of Pujal, San Luis Potosi, Mexico, and named it *Anoptichthys jordani*. This form is genetically continuous with *Astyanax mexicanus* (Fillipi) from which it is distinguishable only in the undeveloped eye and lack of pigmentation. The eye structure of these fish was found to be imperfectly developed and morphologically arrested at a low level of embryological life without powers of visual function, Gresser & Breder (1940).

Especial interest in this species of fish lies in the fact that it is the only known cave species with clear genetic continuity to an outside visual type. Inhabiting warm water and being suitable for laboratory culture, it predicated an experimental approach to problems of blind cave fauna that have vexed biologists. The Aquarium Cave Expedition, Bridges (1940), established this genetic continuity and prepared the bases for further study. It was at first considered that the native habitat could best be utilized for the purpose with the establishment of controlled breeding tanks within the cave water system, but practical considerations caused an abandonment of such an approach.

La Cueva Chica is roughly eighty miles due west of Tampico and some 350 miles northeast of Mexico City, close to the Pan-American Highway at the village of Pujal. Running nearly due south about 1,000 feet from its entrance, the cave ends in a large cul-de-sac five-eighths of a mile from the Rio Tampoan. The character of the cave water system, its flow and the presence of sink-holes in the probable line of direction between cave and river bespoke a close connection, if not a direct one, between these two

systems. Within the cave there were four major pools of water, the innermost of which at the time of our visit was isolated as far as could be determined. The remaining three pools were clearly connected by a small stream. See Bridges (1940) for a map of the cave.

Our thanks are due Mr. James W. Atz for his patient assistance in making a considerable portion of the observations listed in Table III.

DESCRIPTIVE ANATOMY.

All the pools were seined to determine the character of the inhabitants. Grossly there were found three fairly distinct groups, one of which was divisible into two subdivisions. The somewhat arbitrary groups follow: (1) obviously blind with deformed, undeveloped eyes; (2) fish with sunken eyes, (a) covered by skin epithelium, (b) not covered by skin; (3) normal eyes. The sampling is given in Table I. Histological studies were made by serial sections covering a considerable amount of the catch. Variations within the groups as to extent of development both grossly, histologically and to absolute size were numerous.

Group 1 has been previously described in detail, Gresser & Breder (1940), and consists generally of an ocular sac connected to the skin surface by a connective tissue strand either solid or cystic and lined with epithelium. The ocular structures present are defective as to elements and form, the retinal vesicle usually being a lobulated sac without differentiation into iris, pupillary space or developing sensory elements. A crystalline lens is absent and the anterior chamber is absent or represented by an unlined space in a connective tissue stroma. The optic nerve is represented chiefly by a connective tissue cord. See Plate I.

In group 2a the covered, sunken eye presents a better developed globe although malformed as to size and shape. The choroidal gland is usually well developed and the retina is either completely deficient in sensory elements and ganglion cells or large areas of retina are so deficient. A crystalline lens when present is smaller than normal and is accompanied by an irregularly oval-shaped pupillary space; where absent the iris is a weak membrane forming a complete anterior wall to the retinal vesicle. In such conditions an extremely shallow anterior chamber can be found. See Plate II.

The uncovered, sunken eye, group 2b, varies greatly in detail but generally is of small size, deformed but with an anterior chamber, an iris quite well developed with a pupillary space. A lens is present but smaller in diameter in relation to globe diameter than normal. The retina is better stratified than in previous types but deficient irregularly in the rod-cone layer and the corresponding ganglion cell layer. The optic nerve reflects this deficiency in size and relative absence of nerve fibers. See Plate III.

The orbital cavity in group 2 is well developed and where the globe is small or deformed there is a corresponding increase in orbital fat. The extraocular muscles are intact in all groups but apparently their functional use is limited in accordance with the functional capacity of the eye.

In the specimens examined, no symmetry of binocular development could be determined in individuals of groups 1 and 2; especially in group 2 asymmetry was marked as to morphological and functional development. Group 3 was indistinguishable from the normal river fish but microphthalmia was frequent. The normal typically piscine eye structure is shown in Plate IV, based on a specimen from the Rio Tampaon.

Obviously the pool formations present formed ideal and natural breeding tanks and presented *in loco* a highly suggestive explanation for the eye defects and probably as superior and factual experimental methods as human endeavor could devise and control.

As was noted above, population studies in the most isolated pool No. 1 showed a nearly pure strain with completely ineffectual eye structures with an increase in percentage of better developed ocular organs as the probable connection with the outside stream was approached, so that in pool No. 4, closest to the Rio Tampaon, were contained a large percentage of structurally normal eyes.

Most of the inhabitants of pool No. 1 conformed to the ocular pattern first described and which originally were obtained from this pool. Inhabitants of pool No. 2 showed a small percentage of intermediate eyes in which variations in size of the globe, pupillary openings and tissue structures were found but none of which presented morphologically an image-forming organ. In pool No. 3 intermediate eyes were found in greater proportion. In this pool occasional inhabitants showed normally sized eyes, struc-

turally well developed and which clearly permitted definite light behavior patterns. These fish also showed a greater amount of skin pigmentation. This data is detailed in Tables I and II.

Of the inhabitants seined from pool No. 4, only occasional specimens were of least development with a preponderance of better-developed eyes and an increase in the proportion of normals both as to eye structure and pigmentation.

TABLE I.

Eye Condition and Pigmentation of Cave Characins. Expressed in % of catch. Based on 119 specimens.

Location	Eye Condition				
	Blind (1)	Sunken Eye (2)		"Normal" (3)	
		Covered (a)	Uncovered (b)		
Pool 2	85	6	—	9	
Pool 3	16*	8	45	31	
Pool 4	—	9	9	82	

Location	Pigmentation				
	None	Little	Moderate	Considerable	Full
Pool 2	90	2	6	2	—
Pool 3	34*	34	5	8	19
Pool 4	3	29	32	24	12

* Two specimens in this group blind on one side only.

TABLE II.

Association of Eye Condition and Extent of Pigmentation.

Expressed in % of extent of pigmentation. Based on 119 specimens.

Eye Condition	Extent of Pigmentation in Per Cent.				
	None	Little	Moderate	Considerable	Full
Blind (1)	98*	—	2	—	—
Sunken Eye (covered) (2a)	56	33	11	—	—
Sunken Eye (uncovered) (2b)	—	62	15	15	8
"Normal" (3)	2	23	28	23	24

* Two specimens in this group blind on one side only.

BEHAVIOR EXPERIMENTS.

Fishes representing the various types described in the preceding section were shipped alive to the New York Aquarium and form the bases on which the following experiments were made. In addition to these, specimens of the fully blind type which had been bred to the fifth generation by Mr. Albert Greenberg of Tampa, Florida, were used for comparative purposes. These had all been reared in brilliant light. Since Mr. Greenberg never obtained any but fully blind fish it is evident that this form breeds true to type.

Even casual observation shows that these optically various fishes present different types of locomotor behavior. The fully blind individuals, both direct from the cave and Greenberg's fifth generation fish, all keep up a continual swimming activity, constantly wandering in a seemingly

aimless manner. Even at night, if a light were suddenly struck, they would be found to be moving about, giving the impression that they managed to keep on the move at all times. The normal river fish, on the other hand, unless feeding or engaged in some other activity, would remain quiescent in a school, only moving under some evident external stimulus. Those with intermediate eyes unable to form a retinal image but clearly able to receive an optical stimulus from a light source, behaved like the fully blind while those forming a defective image behaved like the normally eyed fish.

Normally eyed fish brought from the cave at first acted nearly like the blind groups but later took on the habits of the typical river fish. It would thus appear that these fishes, unaccustomed to retinal images, took an appreciable time to be able to react to them in an appropriate fashion.

In order better to understand the relation of eye defect to behavior as measured by their locomotor habits, troughs were established

having a lighted and a dark end. These were so arranged that a given area was illuminated with a 60-watt bulb at a distance of three feet while the remainder was shadowed by a cover close to the surface of the water. Thus it was anticipated that by noting the positions of the fish in unit intervals their preferences could be determined in a quantitative manner. In the case of a randomly wandering fish the number of observations obtained over a given area of bottom should then be directly proportional to the whole area if there were no preference being expressed. Significant deviations from such a figure would then be a measure of preference.

As a preliminary experiment a trough was set up 1' by 4' with water 6" deep. Three feet of its length was covered; the remaining area was exposed to light. In all cases the entire tanks were painted black in order to minimize reflections. Into this were placed four fully blind fish of the fifth generation. If these fish were moving strictly at random it then follows that the average of the unit observations which were made

TABLE III.
Results of Behavior Experiments.

Exp. No.	% of		Fish No.	Fish Type	% of		Exp. No.	% of		Fish No.	Fish Type	% of	
	Area	No. of Obs.			Obs. in Light	Expectation		Area	No. of Obs.			Obs. in Light	Expectation
1	.25	100	4	5th Generation	73	73	42	.50	100	1	" "	37	74
2	.25	100	4	" "	111	111	43	.50	100	1	" "	36	72
3	.25	100	4	" "	88	88	44	.50	100	1	" "	29	58
4	.25	100	4	" "	54	54	45	.50	100	1	" "	15	30
5	.25	100	4	" "	96	96	46	.50	100	1	" "	55	110
6	.25	100	4	" "	81	81	47	.50	100	1	" "	46	92
7	.25	100	4	" "	45	45	48	.50	100	3	" "	133	88.6+
8	.25	100	4	" "	55	55	49	.50	100	3	" "	114	76
9	.25	100	4	" "	85	85	50	.50	100	1	No Image Cave	43	86
10	.25	100	4	" "	67	67	51	.50	100	1	" " "	42	84
11	.50	100	4	" "	131	65.5	52	.50	100	1	" " "	11	22
12	.50	100	4	" "	133	66.5	53	.50	100	1	" " "	26	52
13	.50	100	2	" "	29	29	54	.50	100	1	" " "	21	42
14	.50	100	2	" "	35	35	55	.50	100	1	" " "	11	22
15	.50	100	2	" "	24	24	56	.50	100	1	" " "	73	146
16	.50	100	1	" "	42	84	57	.50	100	1	" " "	87	174
17	.50	100	1	" "	23	46	58	.50	100	1	" " "	7	14
18	.50	100	1	" "	24	48	59	.50	100	1	" " "	12	24
19	.50	100	1	" "	12	24	60	.50	100	1	" " "	21	42
20	.50	100	1	" "	28	56	61	.50	100	1	" " "	21	42
21	.50	100	1	" "	37	74	62	.50	100	1	" " "	31	62
22	.25	100	2	Blind Cave	42	84	63	.50	100	1	" " "	25	50
23	.25	100	2	" "	61	122	64	.50	100	1	" " "	23	46
24	.50	75	1	" "	30	80	65	.50	100	1	" " "	26	52
25	.50	100	1	Blind Cave	34	68	66	.50	100	1	Image Cave	48	96
26	.50	100	1	" "	50	100	67	.50	100	1	" " "	3	6
27	.50	100	1	" "	51	102	68	.50	100	1	" " "	3	6
28	.50	100	1	" "	48	96	69	.50	100	1	" " "	0	0
29	.50	100	1	" "	40	80	70	.50	100	1	" " "	0	0
30	.50	125	1	" "	17	27.2	71	.50	100	1	" " "	0	0
31	.50	100	1	" "	37	74	72	.50	100	1	" " "	0	0
32	.50	100	1	" "	38	76	73	.50	100	1	" " "	0	0
33	.50	100	1	" "	27	54	74	.50	100	1	" " "	0	0
34	.50	100	1	" "	31	62	75	.50	100	1	" " "	9	18
35	.50	100	1	" "	53	106							
36	.50	100	1	" "	21	42					Maximum		174
37	.50	100	1	" "	44	88					Average		61.4 -
38	.50	100	1	" "	43	86					Minimum		0
39	.50	100	1	" "	45	90							
40	.50	100	1	" "	51	102							
41	.50	100	1	" "	46	92							

* Not the same specimen used in Experiments 66 to 74.

at five second intervals should come to the figure "1." That is, on strictly random distribution there should be three fish in the dark area and one in the light, or if the fish were schooling there should be four fish visible on the average every fourth observation. In a series of such tests, in which there were 2,100 such observations, the percentage of expectation was 62.3-% in light. This data is given in detail in Table III. Since experiments consist of 100 observations, the expectation from random movement should give 100%. Only one observation reached that figure. As the illuminated area of the trough was changed from time to time in order to avoid the inclusion of some other possible but unknown factor, it can only be concluded that by some means these fish were light sensitive to a slight degree and reacted negatively to such radiations or some secondary associated effect.

Subsequent observations were made in smaller troughs 1' x 2' x 6" deep in which one-half was illuminated and one-half in darkness. Here fish in various smaller numbers were similarly checked and found to show like reactions, as is also set forth in Table III.

Other fishes were then checked in a similar manner and these data are also given in Table III. They are summarized and presented in a condensed form in Table IV. From these tables it is evident that the fully blind fish brought from La Cueva Chica reacted in a manner similar to those of the fifth generation reared in light: 80% avoidance as against 62%. This difference of 17% may actually be significant. The cave fish were larger than the others and possibly overlying tissues of greater consequent thickness may account for the difference, or it may be that there is an increased avoidance to light in subsequent generations.

TABLE IV.
Averages and Ranges of Experiments.

Exp. No.	Type of Fish	No. of Obs.	% of Random Expectation		
			Max.	Mean	Min.
1 to 21	5th Generation	2,100	111	62.3 -	24
22 to 49	La Cueva Chica (Blind)	2,800	122	79.6 +	27
50 to 65	La Cueva Chica (No image)	1,600	154	58.7 +	14
66 to 74	La Cueva Chica (Image)	900	96	12.0	0
75	La Cueva Chica (Image)	100	—	18.0	—
—	River Fish (Normal)	—	Fully unreadable		

Experiments 50 to 65 were performed on a fish that could distinguish light but not form an image. Fish of this group, too, avoided light, 59%, even more vigorously, but here was clear optical detection. Whether or not these fish form a useful retinal image is easy to detect. Fully blind ones, although feebly light-sensitive in the above sense, will not respond to a shadow intercepting the light falling on a tank. Those with full or partial vision react violently by dashing about when a shadow passes across them.

The feeding reactions separate the latter two types. Those with image formation will come to the surface or near it, roll their eyes and make energetic strikes at the food particles as they sink through the water. The blind or merely light-detecting individuals react in no such fashion, merely cruising about mostly on the bottom and apparently finding their food by energetic random movement. One individual seemed to be just at the border line of image formation, normally cruising about like the blind but occasionally finding a sinking particle if it fell between the fish and the light source.

Experiments 66 to 74 were performed on a fish with defective eyes but which could evidently form some sort of image. Experiment 75 was performed on another specimen of similar condition. Here the percentage of expectation of the fish in the light was clearly much lower than in any of the others. Actually these fish spent most of their time just under the shelter of the shadow, obviously looking out into the lighted area, not wandering about but resting quietly.

TABLE V.
Aggregation Data on Blind Specimens.

Exp. No.	Nos. of observations of fish by groups in lighted area				
	0	1	2	3	4
1	48	35	14	2	1
2	34	31	26	8	1
3	38	37	24	1	0
4	52	42	6	0	0
5	32	46	17	4	1
6	43	37	16	4	0
7	62	31	7	0	0
8	50	28	12	1	0
9	35	48	14	3	0
10	44	44	11	1	0
Average	44.7	37.9	14.7	2.4	0.3
11	18	46	24	11	1
12	17	41	34	8	0
Average	17.5	43.5	29.0	9.5	0.5
13	73	24	3		
14	71	23	6		
15	79	18	3		
Average	74.0	27.0	4.0		
22	65	28	7		
23	48	43	9		
Average	56.5	36.5	8.0		
48	16	42	35	7	
49	19	48	32	1	
Average	17.5	45.0	33.5	4.0	

Comparison with Theoretical Probability.

4 fish ¼ area	31.6	42.2	21.1	4.7	0.4
Exp. 1-10	44.7	37.9	14.7	2.4	0.3
4 fish ½ area	6.25	25.0	37.5	25.0	6.25
Exp. 11-12	17.5	43.5	29.0	9.0	0.5
3 fish ½ area	12.5	37.5	37.5	12.5	
Exp. 48-49	17.5	45.0	33.5	4.0	
2 fish ½ area	25.0	50.0	25.0		
Exp. 13-15	74.0	27.0	4.0		
Exp. 22-23	56.5	36.5	8.0		

Normal river fish acted much as the above, but stayed in the light continually unless disturbed by a slight noise or jar to the building. Consequently they were unreadable by this technique since their movements were controlled by external stimuli which were, so far as possible, prevented from reaching them during the course of the experiments.

Since the normal river fish are a closely aggregating and to a considerable extent a schooling type, the annotations previously discussed were examined in reference to the appearance of groups of blind individuals where more than one fish was used in an experiment. These groups were used primarily to discover if any social influences were at work in regard to the light-avoiding reaction. Nothing of this sort appeared.

Since it is evident that the seeing forms show a strong aggregating tendency, the data accumulated on the blind specimens were analyzed so as to show evidences of similar behavior in these fishes if such were present. The data are given in Table V and shown graphically in Text-figure 1 which indicates the results of these tests in reference to random expectation.

As a definite number of fishes was used in each experiment and the lighted bottom area bore a definite relationship to the unlighted, $\frac{1}{4}$ and $\frac{1}{2}$,

in the two types of tanks used, it follows that if the fish were moving at random without reference to light or each other their occurrence in the lighted area in ones, twos, threes, etc., should be predictable according to the binomial formula $(p + q)^n$ expanded for each term, in which

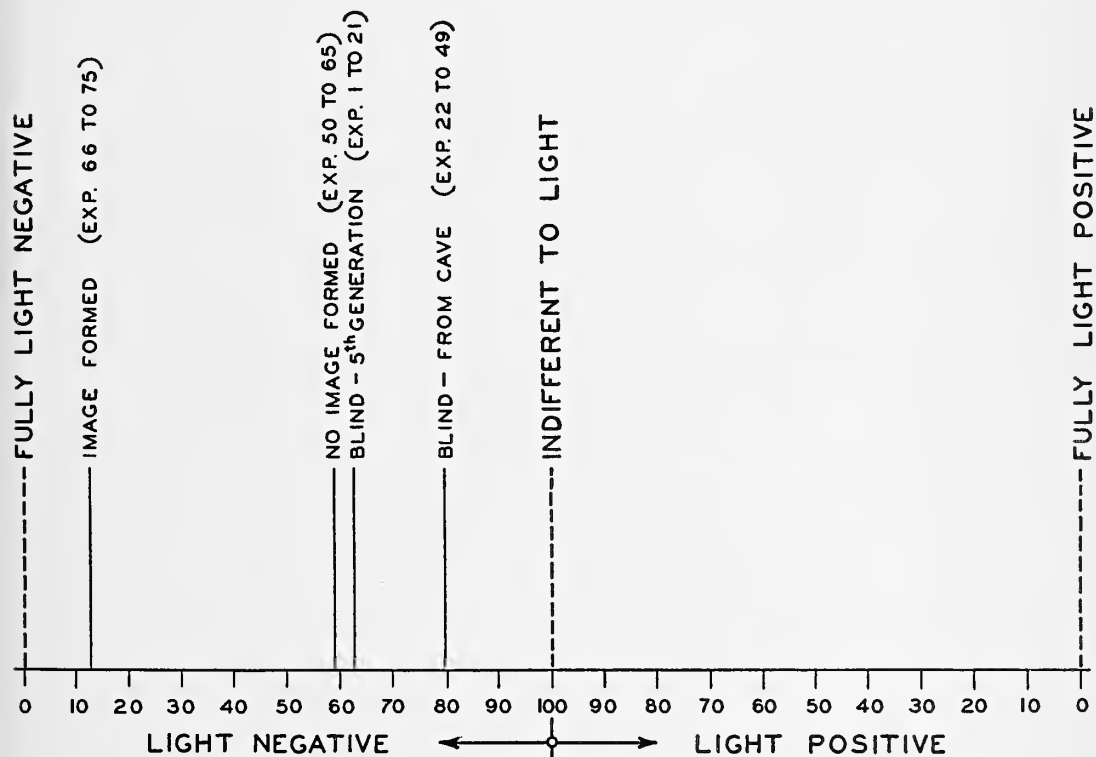
n = number of fishes

p = lighted area

q = dark area

- (1) p^n
- (2) $np^{n-1}q$
- (3) $\frac{n(n-1)}{1 \cdot 2} p^{n-2}q^2$
- (4) $\frac{n(n-1)(n-2)}{1 \cdot 2 \cdot 3} p^{n-3}q^3$
- (5) $\frac{n(n-1)(n-2)(n-3)}{1 \cdot 2 \cdot 3 \cdot 4} p^{n-4}q^4$

These calculations are given in Table V for comparison with the observed figures for the several types of experiment. Some rather interesting features appear which are more clearly shown in Text-figure 2 which presents the comparative data graphically. It may be seen in the



Text-figure 1.

Comparison of behavior in various experiments on light sensitivity in terms of expectancy of random movement.

data of Table V and in Text-figure 2 that in each case there were more observations of the lighted area without fish than random expectation calls for, which is another way of measuring these fishes' light avoidance. In Text-figure 2, graph A, it is clear that the occurrence of the fish in the lighted area in groups follows closely that of the theoretical probability. All appear as less than the expected random value, which again is a measure of their individual light avoidance; the slopes of the connecting lines are in close agreement with random expectation. This is the measure of interlocked (aggregating) behavior and is clearly shown to be a good experimental zero. This graph is based on the largest number of experiments and shows closer agreement with the theoretical than the others based on smaller numbers.

In graph B of Text-figure 2 both the observations noting "no fish" and "one fish" are greater than random expectation while the rest are below it. This is also true for graph C. Except for this feature they are in agreement with graph A although based on much less data. Graph B represents the same fish (fifth generation) as in A while C represents fish brought from the cave. Whatever the interpretation placed on this, these two groups were showing practically identical behavior. It is suspected that the small number of experiments, 3, give as good approximation as could be expected. This becomes more apparent when graph D is considered. Here two sets of different fish show close agreement with A, the "O" observations being above random expectation and the rest below with the trend of these lines being very nearly parallel. It can only be concluded that these fish were moving strictly at random in reference to each other but with a marked avoidance of the lighted area.

DISCUSSION.

From the preceding descriptive histological data, the reactions of the various types with more or less defective vision, coupled with the experimental data on the avoidance of light and the social attitude of the blind examples, certain features become apparent that should have great significance in the development of cave-dwelling blind fish.

If we operate from the assumption that blind and pigmentless animals are able to establish themselves in caves because therein both eyed and eyeless forms are on equal terms, we have two basic factors in effect and interacting; a genetic defect and an environmental peculiarity, the presence of the latter making a continuity and establishment of the former possible. In addition to these it is here experimentally shown that there is a third, a behavior factor, which operates in a positive way.

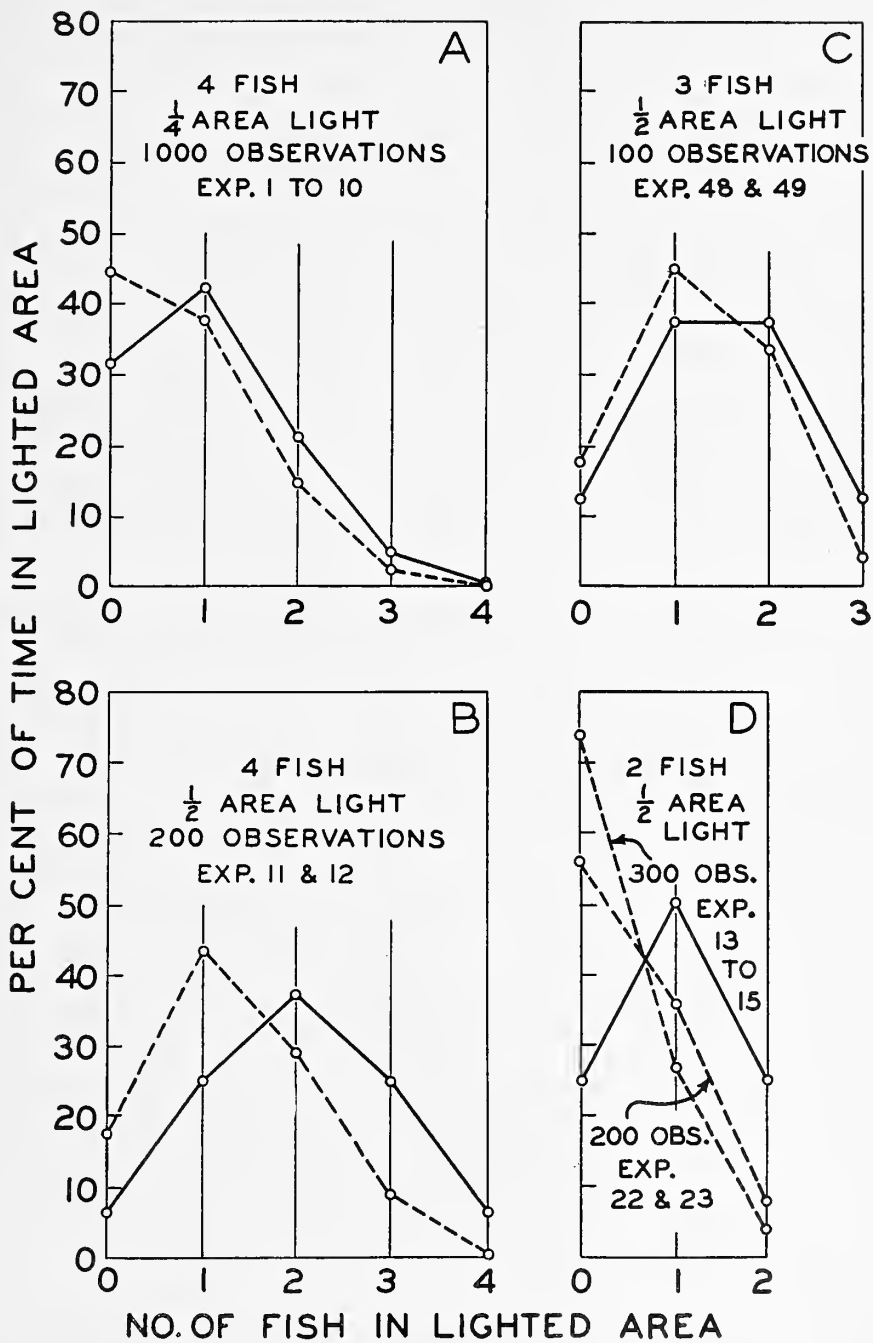
Since the eyed forms use dark retreats only under the stimulus of fright and the blind ones avoid light, by a mechanism as yet not understood, we have a marked schism in the behavior

of fishes otherwise identical and of genetic continuity. Consequently it would seem fair to make the following assumptions on the operation of these factors in a state of nature.

Given a population of river fish carrying one or more appropriately defective genes, individuals with slightly defective sight would seek the shelter of rocks and crevices more than their normally eyed fellows. A cave from which water leaves (as La Cueva Chica) would encourage entry, as these fish tend to work their way up small streams (contranatant) and hold their position in the upper reaches of the rivers by this means. Selection might enter at this point, *i. e.*, fish with defective eyes that might happen to prefer the light would not stay or enter the cave and would either be lost or mixed with the river population, depending on the extent of the handicap of the visual defect. Those that happened to prefer the dark would stay there and transmit their defect, increasing and intensifying it by consanguinity. Once unable to form an image they would not seek light, and if they emerged at night would retreat with sunrise or be lost, as witness what happens in a lighted aquarium between image-forming and non-image forming cave individuals. It appears that the seeing fish attempting to school with the sightless cannot keep up with their continual aimless wandering. This leads to a "resentment" that frequently results in the eyed form attacking and killing the blind. There is no evidence of a substitute sensory mechanism having been developed in the blind fish, for the changing of the position of a rock in an aquarium will result in their swimming into it for a time. Apparently they merely learn where obstacles are by a trial and error development of some sense of space and distances. One specimen with image formation and miniature eyes was successfully kept with two fully blind individuals but took on their habits after about a month and showed no evidence of attack but spent much time following the blind ones. It is probably more than accidental that this fish exhibited great nervousness, dashing about wildly on approach to the aquarium. Returning to the discussion of natural conditions, it would seem that those which found their way out of the cave, and with good eyes, might stay out; however, the current tends to keep them in, as these fish will not normally drop down stream and the period necessary for them to develop an understanding of a retinal image might well be their undoing.

Thus the river and cave populations would tend to stay fairly separate with perhaps the continual entry of defective-eyed fishes accounting for the gradient of eyelessness within the cave.

The question of whether the present population was once fully cut off geographically from the river fish is rather pointless in the light of the above. Certainly some such condition as mentioned above was present at the time of original entry. If some geologic cataclysm cut off these fish for a time, they rejoined sufficiently soon to make a reestablishment of the original condition



Text-figure 2.

Comparison of theoretical randomness with actual behavior showing lack of schooling behavior and negative reactions to light in fully blind fish. Solid line: mathematical probability. Dotted line: observed behavior.

possible, for otherwise the gradient would be quite inexplicable.

If it is thought that some reestablishment of Lamarckian ideas are indicated, it may be pointed out that if the blindness were indeed induced by such a mechanism, the present data do nothing to establish it. Fish that have been forced to live in light for five generations are apparently even more "anxious" to get back into the cave than the present dwellers therein. If this means an increasing sensitivity to light (reestablishment of an eyed condition), it would defeat progress in that direction, for those in the process of regaining vision are the ones most anxious to avoid the stimulus inducing it. Such a mechanism should make for a status quo. A study of possible histological changes in the successive generations of those reared in light for a greater number of generations could help in this connection.

Consequently we are forced to the conclusion that the origin of this blindness is rooted in some genetic defect that was able to find expression in a lightless environment and that the differential behavior of those individuals able to form an optical image as opposed to those merely light sensitive is the determining factor in keeping the population of the cave from a depleting voluntary exit and from too great an admixture of the occasionally entering outside river fish with good vision. The details of the genetic ratios thus become, as far as an explanation of this condition goes, merely of importance insofar as it concerns the speed of the process. Thus if there is a genetic state that produces large numbers of blind fish per generation it would move relatively fast, whereas if the blind individuals are genetically fairly rare it would move more slowly to reach the present state of affairs as found in La Cueva Chica.

The continual locomotor activity and lack of any social grouping on the part of these blind fish would suggest that this feature of behavior has been obliterated, for insofar as experimental evidence goes, schooling is dependent on vision alone in other more or less similarly constituted fishes. Breder & Nigrelli (1935 and 1938) discuss the role of vision in schooling and give full bibliographies.

Since thus far no substitute sensory mechanism has been demonstrated in this form and since nothing in their behavior indicates the presence of such, we infer that these fish are managing to survive in their specialized environment while laboring under a simple loss of function. This may mean that in an evolutionary sense this group is of relatively recent establishment as compared with other blind cave fish that possess elaborate non-visual sensory organs.

Park, Roberts & Harris (1941) have shown that the crayfish of Mammoth Cave, *Cambarus pellucidus* Tellkamp, is light negative in a manner that seems to be fairly comparable to the present findings insofar as it is possible to

compare a sedentary invertebrate to an active fish.

A study of the exact means whereby these fish are enabled to react to the presence of light or on associated phenomena is now being undertaken.

SUMMARY.

1. Fully blind characins from La Cueva Chica are slightly negative to light or some associated effect, as are their fifth generation descendants reared in light.
2. There is a sharp break in the locomotive behavior pattern between those which can form a retinal image and those which cannot.
3. Individuals which form a retinal image have a strong schooling instinct and those which do not, evidence none.
4. Individuals with vision tend to rest quietly in a compact school while the blind continually wander about in an apparently aimless manner.
5. In light, attempts by seeing individuals to school with the blind often terminate by the former killing the latter.
6. Blind individuals in a newly rearranged aquarium will swim into obstacles but will avoid them after a time, apparently by some process of learning.
7. Apparently no substitute mechanism has been developed to function as a substitute for the lost vision.
8. The differential behavior existing between the blind and the seeing is apparently an additional positive factor in the establishment of this cave form.

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EXPLANATION OF THE PLATES.

All fish on the same scale. All eye sections on the same scale.

Photographs of fish by S. C. Dunton. Photomicrographs by M. Sparago.

PLATE I.

- Fig. 1. Unpigmented specimen from La Cueva Chica, Pool No. 2. 53 mm. standard length.
 Fig. 2. Section of eye of the above specimen, showing sunken and overgrown eye with cystic development. (Group 1.)

PLATE II.

- Fig. 3. Scarcely pigmented specimen from La Cueva Chica, Pool No. 3. 47 mm. standard length.
 Fig. 4. Section of eye of the above specimen, showing no exterior chamber, lens or pupillary area development and retina partially developed. (Group 2a.)

PLATE III.

- Fig. 5. Partially pigmented specimen from La Cueva Chica, Pool No. 3. 58 mm. standard length.
 Fig. 6. Section of eye of the above specimen, showing uncovered sunken eye with well developed form, iris poorly developed, retina, choroidal gland and optic nerve undeveloped. (Group 2b.)

PLATE IV.

- Fig. 7. Normal river fish from the Rio Tampaon. 67 mm. standard length.
 Fig. 8. Section of eye of the above specimen, showing the normal optic constitution of these fishes. (Indistinguishable from Group 3.)



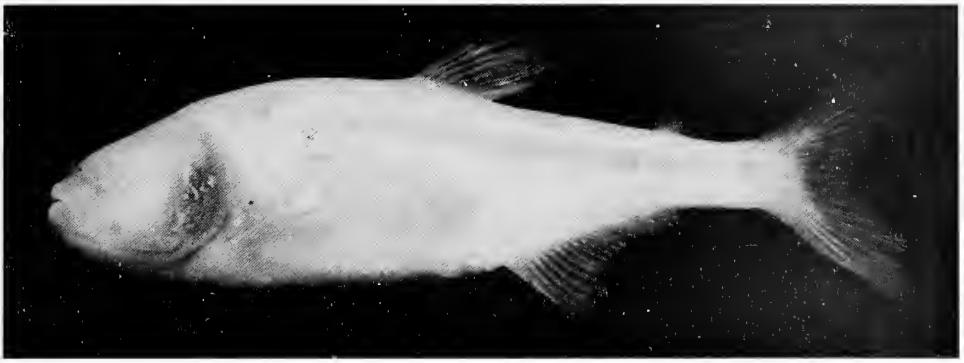


FIG. 1.



FIG. 2.

CORRELATIONS BETWEEN STRUCTURAL EYE DEFECTS AND BEHAVIOR IN THE MEXICAN BLIND CHARACIN.

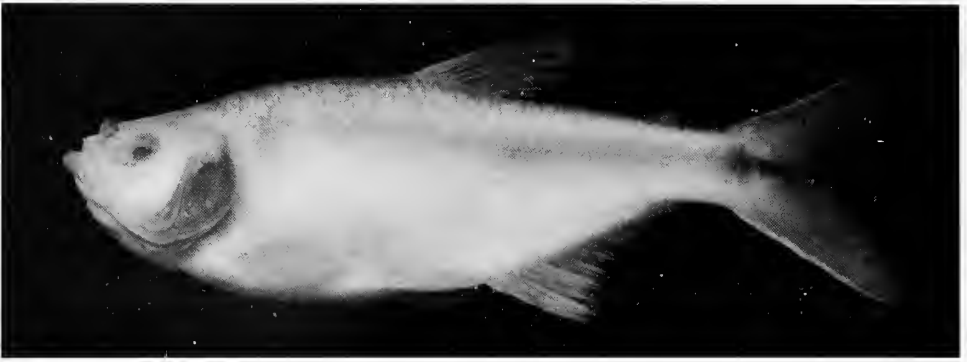


FIG. 3.



FIG. 4.

CORRELATIONS BETWEEN STRUCTURAL EYE DEFECTS AND BEHAVIOR IN THE MEXICAN BLIND CHARACIN.



FIG. 5.

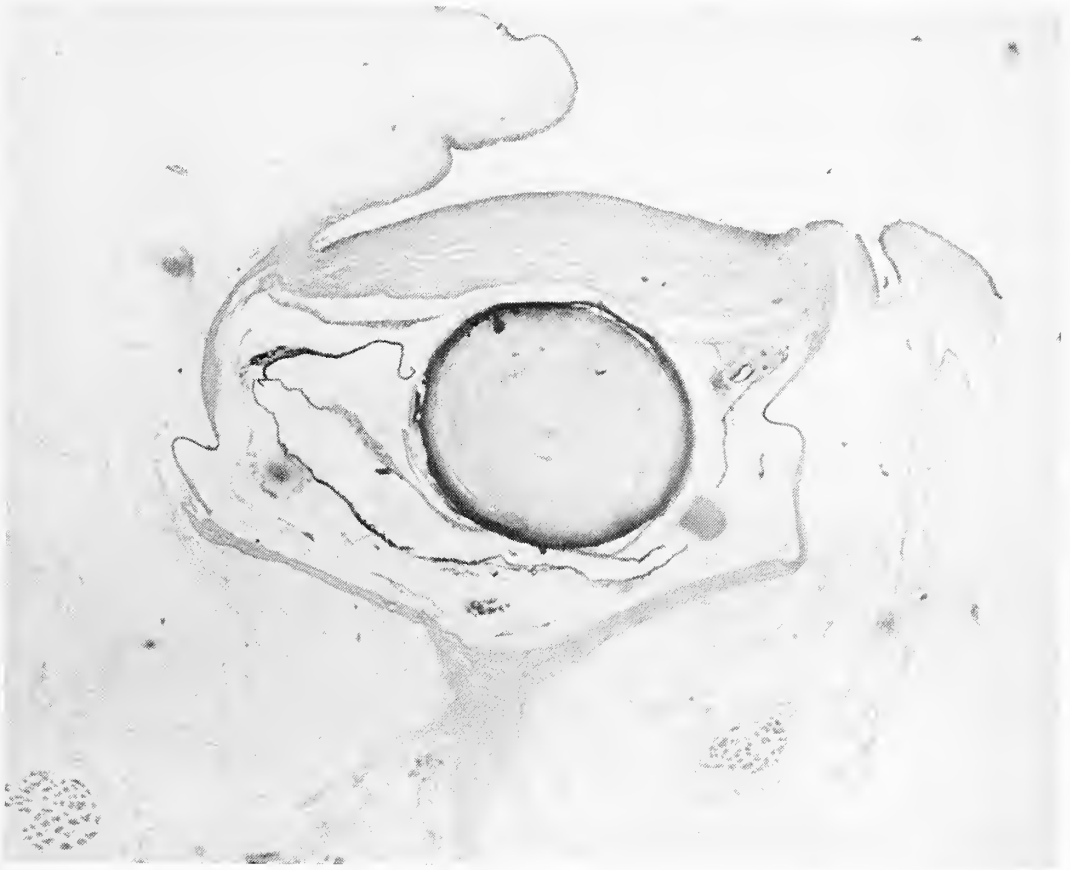


FIG. 6.

CORRELATIONS BETWEEN STRUCTURAL EYE DEFECTS AND BEHAVIOR IN THE MEXICAN BLIND CHARACIN.

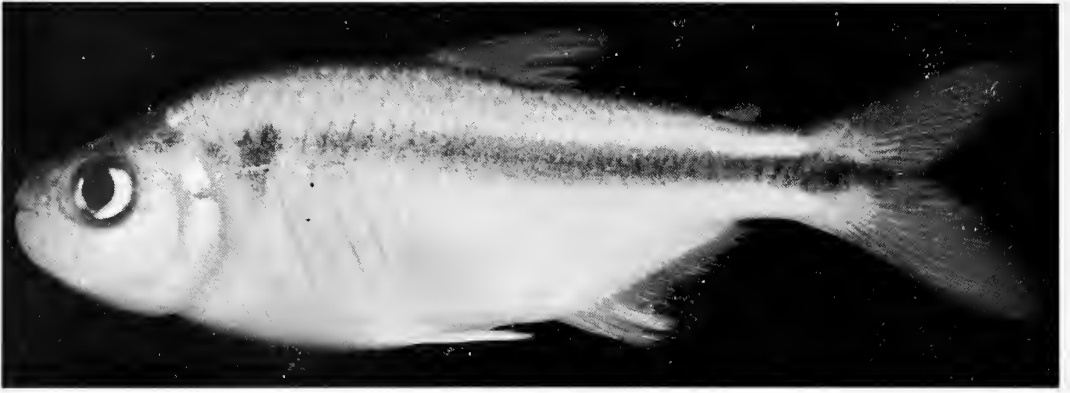


FIG. 7.

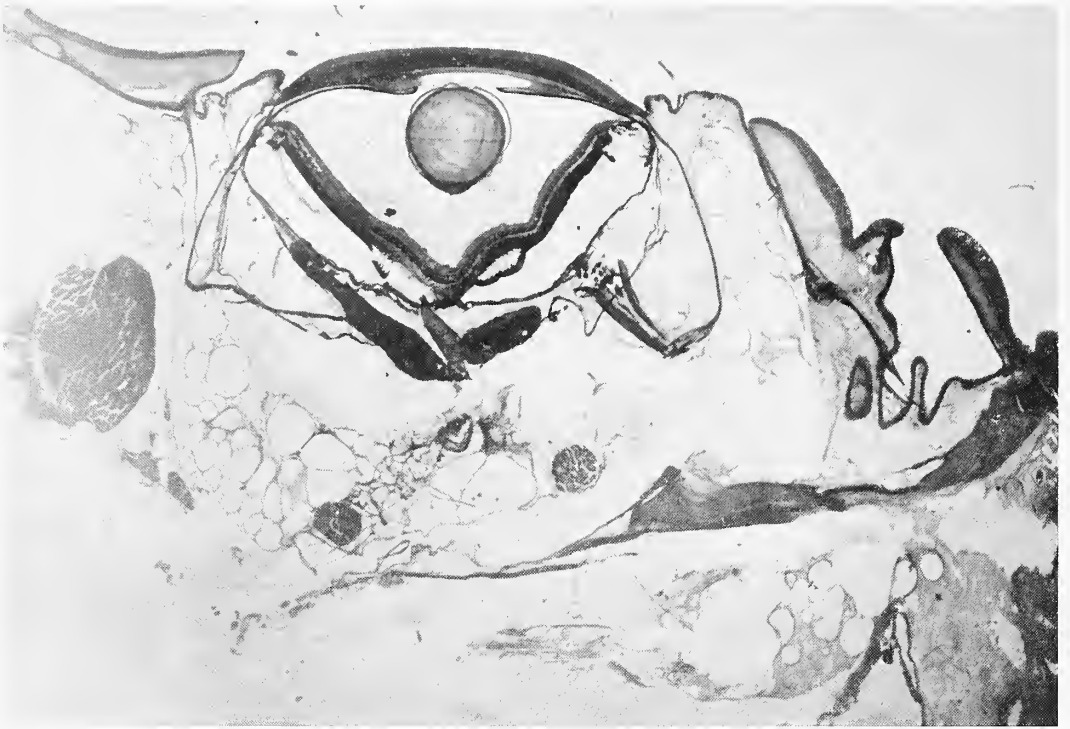


FIG. 8.

CORRELATIONS BETWEEN STRUCTURAL EYE DEFECTS AND BEHAVIOR IN THE MEXICAN BLIND CHARACIN.

17.

On the Species of *Otus scops*.

JEAN DELACOUR.

Owls have long been considered among the most difficult birds to understand, particularly in regard to systematics. Their secretive ways have made it difficult to collect suitable series, while the numerous plumage phases within the same form are often extremely puzzling.

Among them, none are more confusing than those of the genus *Otus*, an ubiquitous group containing the small species known as "Scops owls" in Europe, and "Screech owls" in America. This could, of course, be expected, since nocturnal habits, color and geographical variations are exhibited in the extreme among them.

As early as 1875, Sharpe, in the Catalogue of Birds in the British Museum (Vol. II. p. 44), wrote: "Difficult to understand as all owls are, the species of the genus *Scops*¹ are in every way the most difficult to identify. The impossibility of procuring series of some of the species to study at the same time; the absence of information as to the sequence of plumages from the young stage to that of the adult, and the puzzling way in which some species seem to possess rufous phases, while others do not—these are all problems that only time can solve."

Time has certainly brought us a wider knowledge, but the classification of the Scops owls still leaves much to be desired. Authors differ widely, even today, as to the relationships and affinities of many forms. Particularly those of the smallest birds, related to the European Scops, seem to have remained in a state of confusion. The present paper is an attempt to clear it up as much as possible.

The small Scops owls, resembling *Otus scops*, are widely distributed in Europe, Asia, Africa and, curiously enough, are represented in western North and Central America. They are absent from South America, the Malay and Australasian Islands. To the unprejudiced student, these birds are all obviously so closely related that it is impossible to consider them but as mere subspecies of one species, since it is well known that none of them breed on the same ground. Whenever two forms have been found

together, one has always proved to be a winter migrant.

Scops owls, like many other avian types, are more or less migratory, according to distribution. The species is a dweller in temperate or tropical climates. Nowhere is it found far to the north. In the cooler regions of Europe, Asia and even perhaps northwestern America, it is only a summer nesting visitor, migrating south as soon as the temperature becomes too low. Elsewhere, it does not wander much. It is found at both low and high altitudes, to the latter of which a few forms seem to be confined. As can be expected, the migratory forms have longer and more pointed wings than the resident races.

Two facts have contributed to the obscuration of the status of these owls: first, the presence of different gray, brown and red color phases and their intermediates, which formerly caused much confusion but are now better understood; second, the unfortunate method of classifying them according to the wing formula, which has induced authors to consider as different species birds really hardly separated subspecifically. The relative length of primaries is a late-acquired and relatively unimportant character; a more careful study shows that it is even quite variable in many forms. It certainly cannot stand as of specific value. The figures of wing contours, found in the course of this study, show some of the more typical formulas in different forms. But they represent only one or two of the more frequent formulas. In almost all subspecies there are numerous and important variations.

It has been the mistake of many ornithologists of the last century to base generic and specific distinctions on easy, but often unimportant, characteristics such as wing formula, number of rectrices, etc. When undertaking a general study of the more difficult groups of birds, one is astounded to find that forms so closely related as to be obvious geographical races of the same species often are still widely separated in standard works. Unless a serious revision, based on actual series of specimens, be made, students certainly may be excused for not suspecting affinities which the literature does not suggest.

¹ Now called *Otus*.

Such is the case of our Scops owls. In the Catalogue of Birds in the British Museum, Vol. II, 1875, cited above, Sharpe made excellent use of the materials and of information available in those days. Particularly he states (pp. 45 and 106) that *Scops flammeolus* is the American representative of *Scops giu* (*Otus scops scops*) and that many forms should be considered as races of the European bird. He believes that *Scops senegalensis* is conspecific with *Scops giu*, being "indistinguishable in color," and only smaller (pp. 51-52). He calls subspecies the following forms: *capensis* (*senegalensis*), *pennatus* (*sunia*), *stictonotus*, *japonicus*, *malayanus* and *rufipennis*. Further on (pp. 100-102) he recognizes that the two Andaman Scops owls, *balli* and *modestus*, belong to two different species, all of which is correct. In time, ornithologists arbitrarily came to separate specifically different forms on the basis of the wing formula.

In the last published general list, J. L. Peters (Birds of the World, Vol. IV, 1940) rightly considers all Asiatic forms as subspecies of *Otus scops*, stating in a footnote: "Some authorities consider the Scops owls of Eastern and South Eastern Asia as specifically distinct by reason of their wing formula; other things considered, this difference hardly seems grounds for specific distinctness." But he fails to recognize as such the African and American birds, although they are barely distinguishable in shape, color and wing formula.

My attention was called to the unsatisfactory arrangement of these owls when H. Friedmann & H. G. Deignan (*Journal of the Washington Academy of Sciences*, 20, No. 7, July 15, 1939, pp. 287-291) described a new race, *distans*, from two Siamese specimens, as a subspecies of *Otus senegalensis* to which it is truly very similar. That all the more sedentary tropical forms of Scops, small and round-winged, are very closely related cannot be denied, and the new *distans*, later on also found in South Annam, is curiously similar to the Angolan *hendersoni*, as was pointed out. But it is not very different either from the Indian *sunia*, particularly in its recently discovered extreme red phase, never found among African birds. The same *sunia* in its gray phase also closely resembles *senegalensis* from north-western Africa. It did not, therefore, seem acceptable to consider *distans* as a subspecies of *senegalensis* while *sunia* and other Asiatic forms were left within the species *scops*. Another interpretation had to be found.

The study of materials now at my disposition in America has led me to the following conclusions:

All the small Scops owls of Europe, Asia and western North and Central America, must be considered as geographical representatives—that is to say, as subspecies—of the species *Otus scops*. Differences in size, wing formula and coloration remain well within the normal range of racial variations, the northern migratory birds being duller and having longer and more pointed wings than the more sedentary tropical ones.

None of the different Scops owls of this group breed in the same territory, and wherever they meet, it is only on the winter grounds of northern migrants. All these owls have similar habits, behavior and voice, varying only in a minor degree.

The position of *Otus brucei*, from western Asia, is somewhat peculiar. It looks rather like a pale gray, lightly marked desert edition of *Otus scops*. However, it occupies large areas where the latter also lives and breeds. On close examination it proves to have longer tarsus and tail, and, according to Cheesman, its voice is completely different. No intermediates between these two Scops seem ever to have been found. It must be regarded as a different species. (See Dementiev, Syst. Av. Ross., Paris, 1935, p. 50.)

Otus balli, from the Andaman Islands, where *O. s. modestus* also is found, stands as a separate species, being a larger, heavier bird, with a different color pattern. The very rare *Otus leucopsis* from S. Thomé appears also to be a good species. The small Scops owls of the *rutilus*, *umbra*, *manadensis* and *spilocephalus* groups constitute also as many species, for the same reason. Furthermore, several races of *O. spilocephalus* live on the same grounds as *O. scops*.

I cannot decide whether or not the Philippine forms of Scops owls, as admitted by Peters, really belong to the species *Otus scops* (*calayensis*, *longicornis*, *mindorensis*, *romblonis*, *cuyensis*). I could examine only two specimens of the latter, which seems to be too different in size and color pattern to be included, none of the others having been available. The same can be said of *mantananensis*, from Mantanani Island, north of Borneo. In his "Birds of the Philippine Islands" (London, 1934), Marquess Hachisuka does not consider any of the Philippine Scops owls as closely related to *Otus scops*.

As none of the types and series preserved in European collections can at present be examined, I find it impossible to proceed now to a complete revision of the species *Otus scops*. I can only attempt here to establish a tentative list of its forms, leaving to the future further considerations and appreciations as to the validity of several subspecies. In such cases, I have provisionally accepted Peter's conclusions in his "Birds of the World."

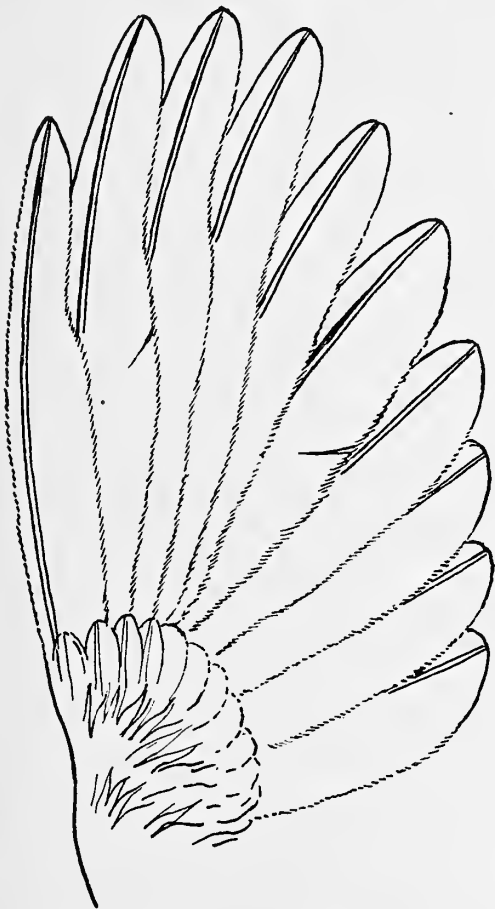
I am simply giving for each form its geographical distribution, formula and dimensions of wings, while stressing interesting points on color phases and plumages from actual examination and also from literature whenever necessary. For general descriptions of the species, I refer my readers to those of *Otus scops scops* easily found in standard works, which can be used for comparison with other subspecies.

All forms of *Otus scops* have the tarsus feathered to the base of the toes, except in a few cases which are mentioned below. Their eyes are usually yellow, but in some forms they vary to brown (*sunia* and allies), while in others they are always dark (*flammeolus*).

In the present study, I have been greatly helped by my friends Dr. J. Chapin, Dr. E. Mayr and Mr. J. Zimmer, of the American Museum of Natural History, New York; Dr. H. Friedmann and Mr. H. G. Deignan, of the National Museum, Washington; Mr. R. M. de Schauensee, of the Academy of Natural Sciences, Philadelphia; and Mr. J. C. Greenway, of the Museum of Comparative Zoology, Cambridge, who kindly loaned me the specimens in their care.

I have made particular use of the valuable information found in the more recent works by Hartert, Mr. W. L. Sclater, Mr. E. C. Stuart Baker, Dr. D. A. Bannerman, Dr. J. Chapin, and I am much indebted to the researches of Dr. E. Stresemann (*Mitt. Zool. Mus. Berlin*, 12 (1) 1925, pp. 191-195); Dr. P. Dementiev (*Syst. Av. Ross.*, Paris, 1935, pp. 49-51); Dr. H. Friedmann and Mr. H. G. Deignan, and of L. Peters (cited above). The drawings of wings were executed by Mr. Lloyd Sandford. I tender them all my grateful thanks.

1. *Otus scops scops*.



Text-figure 1.

Otus scops scops. ♂ Lanusci, Sardinia, 2-I-1901. (Amer. Mus. Nat. Hist., New York.)

Stryx scops Linnaeus. *Syst. Nat.*, ed. 10, 1, 1758, p. 92. (Europe, restricted to Italy.)

Distribution: Breeds in Central and Southern Europe, north to central France, northwestern Germany, the Alps, Austria, Hungary, southwestern Russia, the Canary Islands, North Africa. Winters in West Africa, east to Ethiopia and south to Uganda.

Wing Formula: 3rd primary longest, 2nd subequal; 1st primary long, equal to 6th, or between 5th and 6th, or 6th and 7th.

Dimensions of Wings: ♂ 147-161 mm. ♀ 148-166 mm.

Color Phases: Amount of gray and reddish-brown variable, producing gray and brown phases, but no clear red phase. The markings vary much in intensity.

2. *Otus scops cycladum*.

Pisorhina scops cycladum Tschusi. *Orn. Jahrb.*, 15, 1904, p. 21. (Naxos).

Distribution: Resident in the Cyclad Islands and Crete. (Not examined.)

3. *Otus scops pulchellus*.

Stryx pulchella Pallas. *Reise Versch. Prov. Russo. Reichs*, 1, 1808, p. 456. (Siberia.)

Distribution: Breeds in Russia, east of Longitude 35° East and north to Latitude 56°; Caucasus, southwestern Asia north to Irtysh, east to Krasnoyarsk, south to Kirghiz Steppe, Ferghana, Tabargatai and the Altai. Winters in the upper Nile Valley, southwestern Asia and northwest India.

Wing Formula: Same as in *Otus scops scops*.

Dimensions of Wings: ♂ 150-164 mm. ♀ 156-163 mm.

Color Phases: Very close to *Otus scops scops*, but brown phase almost absent; only a few specimens have a little more rufescent tinge than others. General color more grayish and more uniform, particularly on the upper parts. (See P. Dementiev, *Systema Avium Rossicarum*, Paris, 1935, pp. 49-51.)

4. *Otus scops turanicus*.

Pisorhina scops turanicus Loudon. *Orn. Monatsb.*, 13, 1905, p. 129. (Kara-Korum, Transcaspia).

Distribution: Transcaspia, Bukhara, northern Persia, Armenia?

Wing Formula: Like *Otus scops pulchellus*.

Dimensions of Wings: Similar to precedent.

Color Phases: According to Dementiev (*loc. cit.*). This form is lighter still than *pulchellus*; pattern very fine, but well marked with more white markings. The one specimen in the American Museum of Natural History, from Mt. Asilmadog, Transcaspia, answers well the above description. Spots and shades very clear on pale ground color.

5. *Otus scops cyprius*.

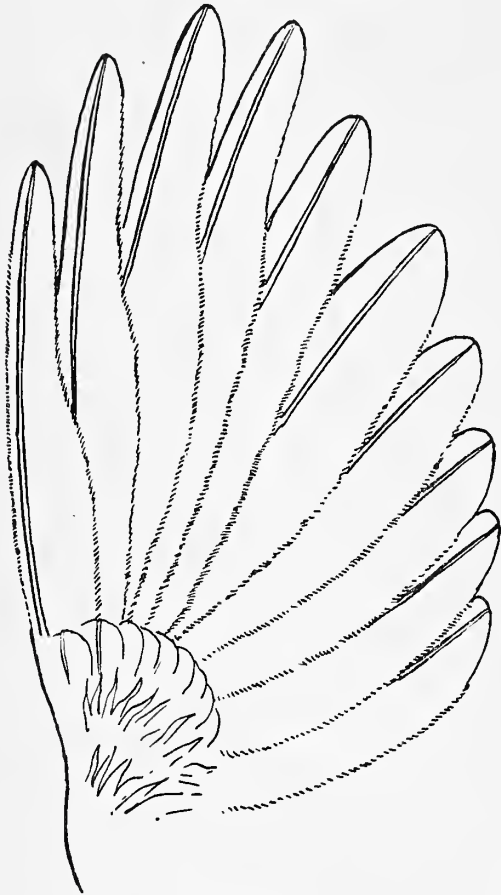
Scops cypria Madarasz. Termes, 24, 1901, p. 272. (Livadia, Cyprus.)

Distribution: Island of Cyprus. (Resident.)

Wing Formula: Same as in *Otus scops scops*.

Dimensions of Wings: ♂ 150–163 mm. ♀ 153–167 mm.

Color Phases: Gray phase only; markings very distinct and rather strongly resembling those of the gray phase of *Otus scops sunia* and *Otus scops senegalensis*.

6. *Otus scops stictonotus*.

Text-figure 2.

Otus scops stictonotus. ♀. Chingwangtao, Tchili, N. China, 14-IX-1913. (Mus. Comp. Zool., Cambridge, Mass.)

Scops stictonotus Sharpe. Cat. Birds Brit. Mus., 2, 1875, p. 54. (China).

Distribution: Breeds in Amurland, Ussuriland, great Chigan, Manchuria, down to central China. Winters in South China, Tonkin, Laos and Siam. Hainan?

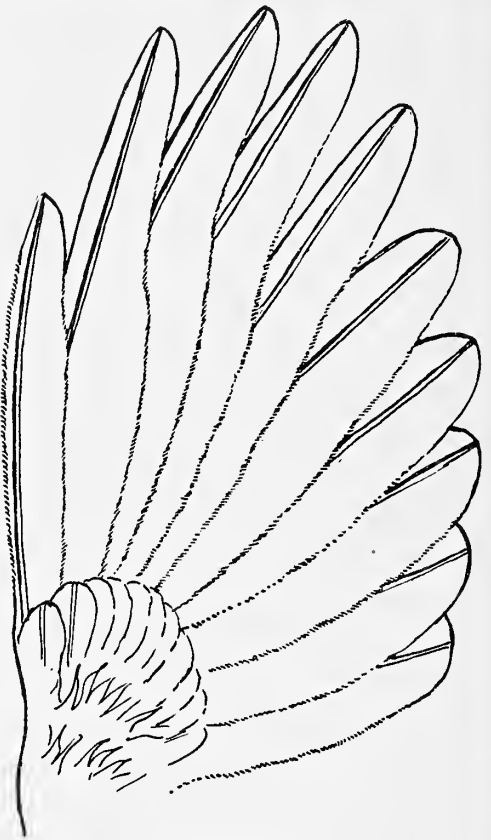
Wing Formula: In this form and in all the fol-

lowing ones, the first primary is much shorter and the wing more rounded than in the preceding five northwestern birds.

The formula is rather variable. In most of the specimens, the 1st primary is between 6th and 7th, but in others 1st equals 7th or 1st equals 6th, or 1st is between 7th and 8th. The 4th primary is the longest, but in a few cases, the 3rd is equal to it. The 2nd primary is equal to 5th, or between 5th and 6th. There are many variations as to the relative length of the different primaries.

Dimensions of wings: ♂ 137–152 mm. ♀ 137–154 mm.

Color Phases: Brownish-gray and bright red phases are found in this form with many intermediate plumages. More clearly marked than *Otus scops scops*, and generally darker and brown-



Text-figure 3.

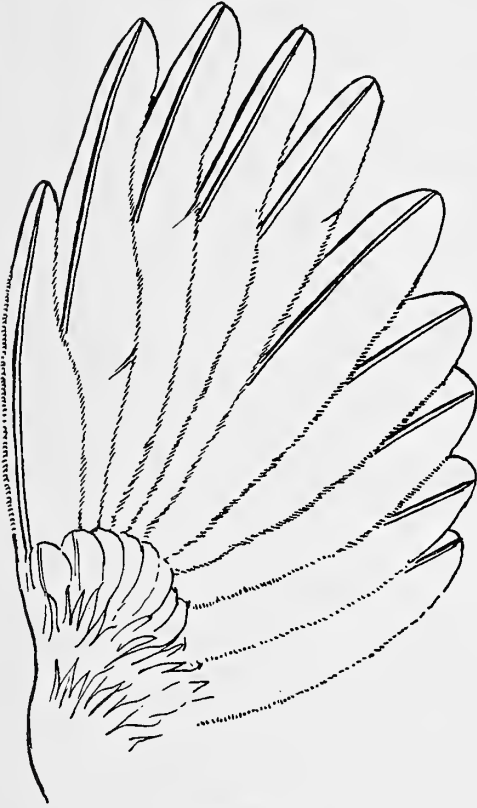
Otus scops stictonotus. ♀. Eastern Siberia, 16-IX-1900. (Amer. Mus. Nat. Hist., New York.)

er. Differs very slightly from the following form, *Otus scops japonicus*, having coarser and clearer marking below and in being a little more mottled above, with a rather clearer indication of a collar. But the two races are very close and only a series can show differences on an average. A few specimens are indistinguishable (about 10%).

All continental specimens, including some from

Tonkin, Laos and Siam, belong to this race. Two from Formosa, collected during the winter, seem to belong to *japonicus*. Two dark specimens from Siam, in the Academy of Natural Sciences of Philadelphia, mentioned by Friedmann & Deignan as intermediates between *malayanus* and *japonicus*, belong, in my opinion, to *stictonotus*. They have the whole tarsus feathered, unlike *malayanus*, and although dark, can be matched by several Chinese specimens. *Modestus* is confined to the Andaman and perhaps also the Nicobar Islands.

7. *Otus scops japonicus*.



Text-figure 4.

Otus scops japonicus. ♂. Toyoashi, Mikawa, Japan, 20-X-1922. (Mus. Comp. Zool., Cambridge, Mass.)

Otus scops japonicus Temminck & Schlegel. Fauna Jap., 1850, p. 27. (Japan.)

Distribution: Japan, from Hokkaido to Kiusiu. Formosa in winter?

Wing Formula: Same as in *Otus scops stictonotus*.

Dimensions of Wings: ♂ 143-146 mm. ♀ 142-151 mm.

Color Phases: Brown and red phases as in *stictonotus*. Less clearly marked below and more uniform above, but barely recognizable.

8. *Otus scops interpositus*.

Otus japonicus interpositus Kuroda. *B. O. C. Bull.*, 43, 1923, p. 122. (S. Borodino Island).

Distribution: Borodino Island. (Not examined.)

9. *Otus scops botelensis*.

Otus sunia botelensis Kuroda. *Tori*, 5, 1928, p. 26. (Botel Tobago.)

Distribution: Island of Botel Tobago. (Not examined.)

10. *Otus scops elegans*.

Ephialtes elegans Cassin. *Proc. Acad. Nat. Sci. Philadelphia*, 6, 1852, p. 185. (Off coast of Japan.)

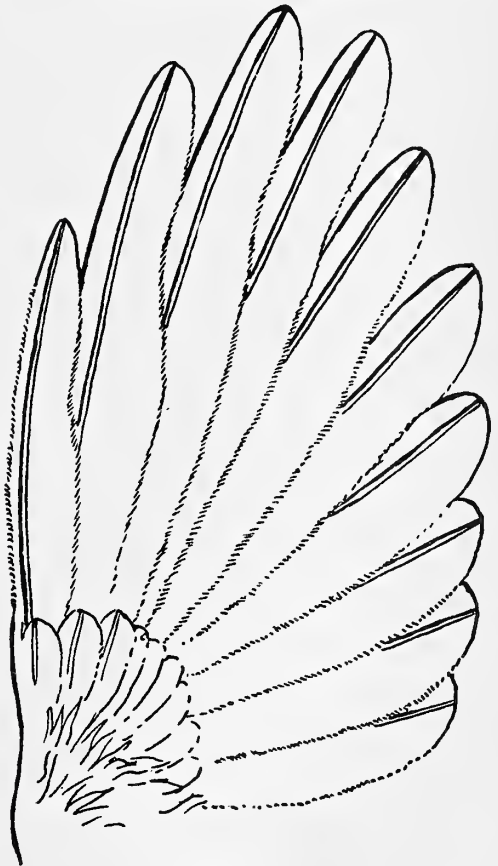
Distribution: Riu-Kiu Islands.

Wing Formula: As in *Otus scops stictonotus*. Same variations.

Dimensions of Wings: ♂ 160-170 mm. ♀ 163-167 mm. Very large size.

Color Phases: All specimens are in brown plumage; series very even. Resemble the brown phase of *Otus scops japonicus*. No red phase recorded.

11. *Otus scops malayanus*.



Text-figure 5.

Otus scops malayanus. ♀. Taiping, Perak, Malay States, 11-XI-1913. (Amer. Mus. Nat. Hist., New York.)

Scops malayanus Hay. *Madras Journ. Lit. Sci.*, 13, pt. 2, 1847, p. 147. (Malacca.)

Distribution: South China (breeding?) down to the Malay Peninsula, where it is probably a winter visitor. Range still uncertain. Specimens examined from Perak, November 1 (Malay P.), Sui-fu (Szechuan), Mongtse, October 12 (Yunnan) and Yenping, March 16 (Fokhien).

Wing Formula: Variable—usually 3rd and 4th primaries longest, equal or subequal; 1st between 6th and 7th, not differing from *Otus scops stictonotus* and others.

Dimensions of Wings: ♂ 135–150 mm. ♀ 146–150 mm.

Color Phases: Brown and bright red phases, but in all cases distinctly darker than *stictonotus*. Intensity of markings much the same, rather greater below. Lower quarter of tarsus naked.

12. *Otus scops modestus*.

Scops modestus Walden. *Ann. and Mag. Nat. Hist.*, (4), 13, 1874, p. 123. (Port Blair, S. Andaman Island.)

Distribution: Andaman Islands—Nicobar Islands?

Wing Formula: 4th primary the longest, but little longer than 3rd and 5th; 1st between 8th and 9th.

Dimensions of Wings: ♂ 143 mm. ♀ 140–142 mm.

Color Phases: Brown phase only; series (5) very even (collected at Port Blair in May, September and December). Above faintly spotted as in *Otus scops japonicus*; below more clearly marked, almost like *sunia*, with a good deal of white. Scapulars with pure white marks. Lower quarter of tarsus naked as in *Otus scops malayanus*. Andaman *Otus scops* are clearly different from Indo-Chinese, Burmese and S. Chinese specimens. They are less mottled above, and more below, and have the lower part of the tarsus unfeathered. The subspecific name *modestus* must be restricted to them. Nicobar birds (not examined) may be the same.

13. *Otus scops distans*.

Otus senegalensis distans Friedmann & Deignan. *Journ. Washington Acad. Sci.*, 20, p. 7, 15, July, 1939, p. 287. (Sala Metha, Chiangmai, N. Siam.)

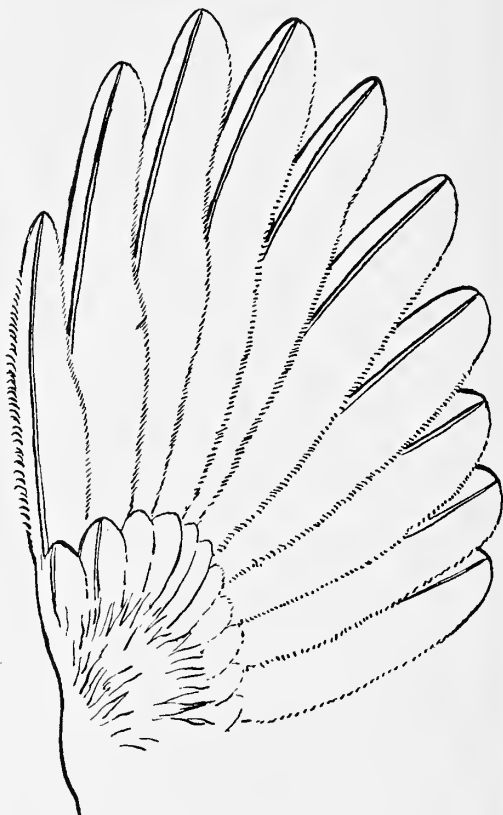
Distribution: Siam and S. Indo-China. (Resident.)

Wing Formula: 4th primary the longest; in the four known specimens, the wing formula varies:

1. (Type) ♀ Sala Metha, N. Siam, Feb. 20, 1936 (gray phase).

- 1st = 8th
- 2nd between 5th and 6th
- 3rd = 5th
- 4th slightly longer only

- 2. ♀ Pha Chang, S. Siam, March 20, 1927 (gray phase)
1st between 7th and 8th
2nd = 5th
3rd between 4th and 5th
- 3. ♂ Dalat. S. Annam, August, 1939 (gray phase)
1st between 8th and 9th
2nd between 5th and 6th
3rd and 5th subequal, 4th barely the longest
- 4. ? Finmon, S. Annam, November, 1939 (red phase)
1st between 9th and 10th
2nd between 7th and 8th
3rd = 5th
4th the longest

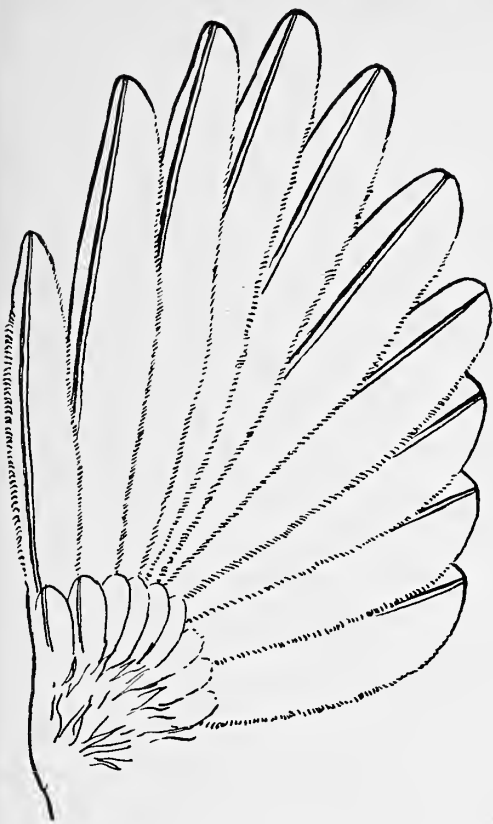


Text-figure 6.

Otus scops distans. Type. ♀. Sala Metha, N. Siam, 15-VII-1936. (U. S. Nat. Mus., Washington, D. C.)

Dimensions of Wings: ♂ 142 mm. ♀ 142 (type) and 127 mm. ?—128 mm.

Color Phases: Gray phase very similar to gray phase of *Otus scops hendersoni* from Angola, with very strong and clear markings and much white and gray above and below. Also near gray phase of *Otus scops sunia*, but still more mottled and



Text-figure 7.

Otus scops distans. ?. Finmon, S. Annam, XI-1939. (U. S. Nat. Mus., Washington, D. C.)

less brownish. Red phase very bright and close to the red phase of *sunia*, with stronger black marks above and more white and gray below.

14. *Otus scops sunia*.

Scops sunia Hodgson. As. Res. 1836, p. 175. (Nepal).

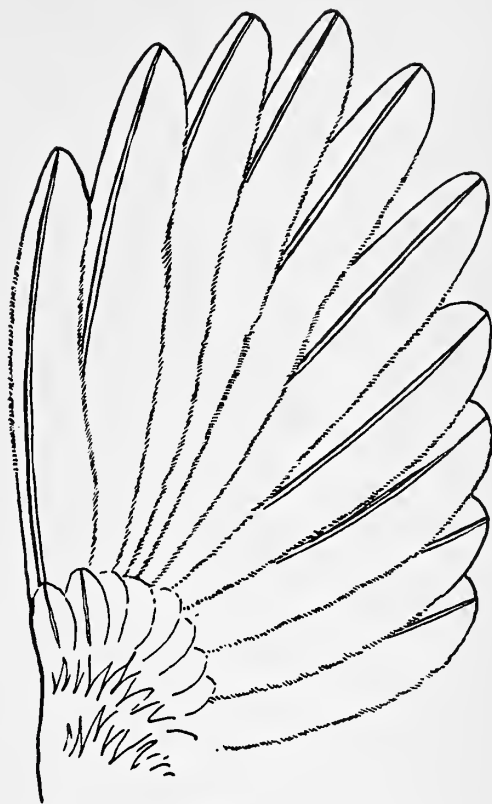
Distribution: Himalaya, from Kumaon to Upper Burma, Punjab, Central Provinces, Bengal, Assam and the greater part of Burma.

Specimens from Dalu in the Chin Hills (Burma) in the gray phase, and a series from Upper Assam, in the red phase, are inseparable from Himalayan specimens.

Wing Formula: 4th primary the longest; 1st usually between 7th and 8th, but formula very variable and sometimes 1st = 6th. In one Assamese bird, the 4th and 5th are equal, the 3rd is hardly longer than the 6th, and the 2nd is between 6th and 7th. In four others from the same locality, 3rd = 5th and 2nd = 5th.

Dimensions of Wings: ♂ 136-147 mm. ♀ 140-154 mm.

Color Phases: Very gray and very red phases, and some brown intermediates. Gray birds are



Text-figure 8.

Otus scops sunia. ♀. Upper Assam, India, 5-1-1903. (Amer. Mus. Nat. Hist., New York.)

strongly mottled above and much resemble some specimens of *Otus scops senegalensis*. All are strongly marked below and above with much white, but never so gray and white as *Otus scops distans*. The weakly marked gray birds resemble the more strongly marked *Otus scops scops* in color.

15. *Otus scops rufipennis*.

Otus rufipennis Sharpe. Cat. Birds B. M. 2, 1875, p. 60. (Eastern Ghats, Madras.)

Distribution: Indian Peninsula south from Bombay and Madras.

Wing Formula: "Similar to *Otus scops scops*," according to Baker, but in fact like *sunia*, with a short first primary.

Dimensions of Wings: "122-135 mm."

Color Phases: "Similar to *sunia*, but rather darker." (Stuart Baker.)

One ♂ specimen from Jagalled, Bombay Pr., in the Koeltz collection, is very near *pulchellus* in coloration, with more rufous on the wings.

16. *Otus scops leggei*.

Otus cunia leggei Tiechurst. *Ibis*, 1923, p. 242. (Kotmalie, Ceylon.)

Distribution: Ceylon. (Not examined.)

Wing Formula: "Similar to *Otus scops scops*." (Baker.) But more likely similar to *sunia*.

Dimensions: "119–127 mm."

Color Phases: "Differ from other races in being much smaller and darker." (Stuart Baker.)

17. *Otus scops senegalensis*.

Scops senegalensis Swainson. *Birds W. Afr.* 1, 1937, p. 127. (Senegal.)

Distribution: Northern west Africa, east to Egyptian Sudan, south to the border of the Congo. Not found in heavy forest areas.

Wing Formula: 1st primary = 6th, or between 6th and 7th, but usually between 7th and 8th; 3rd between 4th (the longest) and 5th; 2nd between 5th and 6th.

Dimensions of Wings: ♂ 123–136 mm. ♀ 130–138 mm.

Color Phases: Gray and brown phases, but no bright red phase in any of the Ethiopian Scops owls, which are all very closely related. Resembles much the similar phases of *Otus scops sunia*. Much individual variation in the intensity of markings. Some are very close in color to certain well marked *Otus scops scops*.

18. *Otus scops pygmeus*.

Scops pygmea C. L. Brehm. *Vogelfag*, 1855, p. 43. (Sennar.)

Distribution: Southern and eastern Egyptian Sudan and northern Abyssinia.

Wing Formula: Similar to *Otus scops senegalensis*.

Dimensions of Wings: ♂ 130 mm. ♀ 134 mm.

Color Phases: Hardly different from *Otus scops senegalensis*, but said to be rather more faintly marked, tending to *Otus scops scops*. Probably not valid, but comparative materials are insufficient to decide.

19. *Otus scops coecus*.

Otus senegalensis coecus Friedmann. *Auk*, 1929, p. 251. (Sadi Malka, Ethiopia.)

Distribution: Abyssinia, except northwestern, Somaliland and Kenya, south to north Guaso Nyiro River.

Wing Formula: Similar to *Otus scops senegalensis*.

Dimensions of Wings: ♂ 120–133 mm. ♀ 119–121 mm.

Color Phases: Gray and brown. Described as darker, more heavily vermiculated than any

other race, which is not borne out by some of the few specimens examined.

20. *Otus scops socotranus*.

Scops socotranus Ogilvie-Grant & Forbes. *Bull. Liverpool Mus.*, 2, 1899, p. 2. (Socotra.)

Distribution: Socotra Island. (Not examined.)

21. *Otus scops pamelae*.

Otus senegalensis pamelae Bates. *B. O. C. Bull.*, 57, 1937, p. 150. (Dailami, Arabia.)

Distribution: Arabia. (Not examined.)

22. *Otus scops ugandae*.

Pisorhina ugandae Neumann. *Journ. Fr. Orn.*, 47, 1899, p. 56. (Kwa Mtessa, Uganda.)

Distribution: Upper Uelle east to Barh-el-Jebel, and south to Lake Kivu and Ankole.

Wing Formula: Similar to *Otus scops senegalensis*.

Dimensions of Wings: ♂ 131–143 mm. ♀ 135 mm.

Color Phases: As in *Otus scops senegalensis*, but less gray, with markings on breast more contrasted.

23. *Otus scops feae*.

Scops feae Salvadori. *Mem. R. Ac. Sc. Torino*, 53, 1903, p. 95. (Island of Anobon.)

Distribution: Island of Anobon (W. Africa). (Not examined.)

Color Phases: "Resembles *Otus scops senegalensis*, but darker in color. The black shaft-streaks of the underparts broader." (Bannerman.)

24. *Otus scops graueri*.

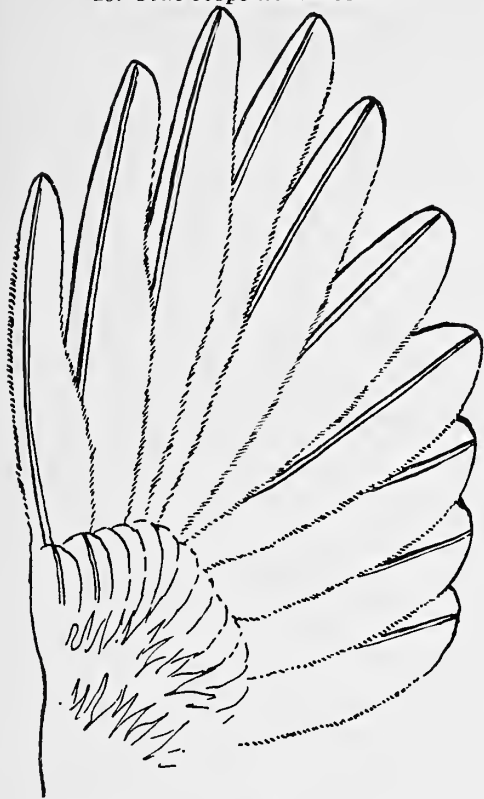
Otus senegalensis graueri Chapin. *Am. Mus. Nov.*, 1, no. 412, 1903, p. 4. (Lueba, northwest shore of Lake Tanganyika.)

Distribution: Coast of Kenya, Tanganyika east to Katanga.

Wing Formula: Similar to *Otus scops senegalensis*.

Dimensions of Wings: ♂ 124–128 mm. ♀ 129–136 mm.

Color Phases: Differ slightly from *Otus scops ugandae* by "having the crown, back, rump and lesser wing coverts more heavily washed with rufous, while the rufous markings on the basal half of the breast-feathers are paler and less extensive." (Chapin.) Series are very even.

25. *Otus scops hendersoni*.

Text-figure 9.

Otus scops hendersoni. ♀. Bailundu, Angola, 19-VIII-1901. (Amer. Mus. Nat. Hist., New York.)

Ephialtes hendersoni Cassin. *Proc. Acad. Nat. Sci. Philadelphia*, 6, 1852, p. 186. (Off Novo Redondo, Angola.)

Distribution: Angola and southwestern Congo.

Wing Formula: Similar to *Otus scops senegalensis*.

Dimensions of Wings: ♂ 128-136 mm. ♀ 134-140 mm.

Color Phases: Often very gray and clearly mottled, and almost similar in color to gray *Otus scops distans* from southeastern Asia, but many specimens are also strongly washed with rufous.

26. *Otus scops pusillus*.

Pisorhina capensis pusilla Gunning & Roberts. *Ann. Transvaal Mus.*, 3, 1911, p. 111. (Nama-bieda, Portuguese East Africa.)

Distribution: Mozambique to borders of Nyasaland and S. Rhodesia. (Not examined.)

27. *Otus scops intermedius*.

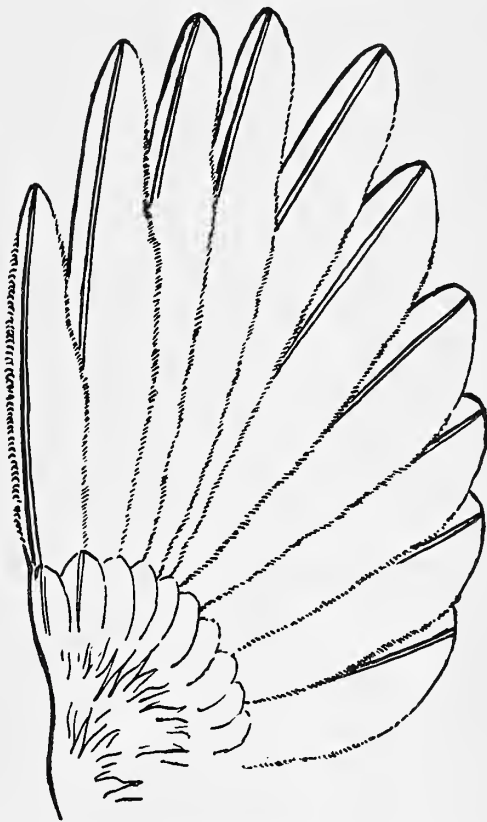
Pisorhina capensis intermedia Gunning & Roberts. *Ann. Transvaal Mus.*, 3, 1911, p. 111. (Pretoria.)

Distribution: South Africa, except the Cape Province. (Not examined.) Doubtfully valid. Probably synonym of *Otus scops latipennis* (= *capensis* auct.).

28. *Otus scops latipennis*.

Scops latipennis Kaup. *Jardine's Contr. Orn.*, 1852, p. 110. (Caffraria.)

Distribution: Cape Province. (Not examined.) "Tarsus not feathered down to the toes."

29. *Otus scops flammeolus*.

Text-figure 10.

Otus scops flammeolus. ♂. Sunnyside Canyon, Huachuco Mountains, Arizona, 4-V-1934.

Scops flammeola Kaup. *Jardine's Contr. Orn.*, 1852, p. 111. (Mexico.)

Distribution: Southern British Columbia, south through the mountains of western United States and Mexico, east to New Mexico.

Wing Formula: 1st primary between 7th and 8th, or between 6th and 7th, more usually = 8th; 4th longest or equal to 3rd; 2nd between 5th and 6th.

Dimensions of Wings: ♂ 128-138 mm. ♀ 129-144 mm.

Color Phases: In the gray phase, resembles

Otus scops sunia and *Otus scops senegalensis*. No bright red phase as in Asiatic Scops owls, but a brown rufescent one of variable intensity as in the African races. Always differs from all others in the variable russet coloration of the upper throat, top of the head, feathers around the eyes, egrets and facial disk. Under parts much like those of *distans* and *hendersoni*, very gray; upper parts less mottled, more like those of *sunia*.

30. *Otus scops rarus*.

Otus flammeolus rarus Griscom. *Auk*, 1937, p. 391. (Dueñas, Guatemala.)

Distribution: Highlands of Guatemala. (Not examined.) "Similar to *flammeolus*, but in the intermediate phase more brownish, less purely gray in ground color above; ochraceous longitudinal wing-bars richer and deeper, broken collar across hind neck tawnier and brighter, less brownish; most of the occiput bright tawny ochraceous rather than rusty brown; chestnut areas on side of head and auricular region rather brighter and more richly colored; brownish or rusty washing on underparts brighter and tawnier." (Griscom, *Ibis*, 1935, pp. 549-550.)

18.

A New Genus of Kaleege Pheasants.

MARQUESS HACHISUKA.

† *Delacourigallus* gen. nov.

Gennaesus edwardsi Oustalet, 1896. Type, by original designation.

As far as we know at present, the new genus includes two distinct species of Kaleege pheasants known only from restricted ranges in Annam, *edwardsi* and *imperialis*. Until now they have been considered to be congeneric with *Hierophasis swinhoii* of Formosa, but the members of the new genus are much smaller than *H. swinhoii*; the wattles are much less developed and project very little beyond the outline of the head during display, while in *Hierophasis* they stick out vertically above and below the head. The tail in *Hierophasis* is more elongated, each feather becoming narrower and more pointed toward the end, the central pair, which is curved downward, being longer than the second. The female of the new genus is plain buffish or rufous brown, while in *Hierophasis* the chin is white and the underparts of the body are lighter than the upper; the entire body, including the central pair of tail feathers, is mottled and barred.

The general color pattern of the females in the new genus is extraordinarily similar to *Lobiophasis* and far more removed from *Hierophasis*.

Remarks: It is interesting to note that *Delacourigallus*, *Hierophasis* and *Lobiophasis* are alike in many important points. All the males have metallic blue and green scale-like feathers on the dorsal part of the body, steel blue being the predominant color. The cocks of *Hierophasis* have their tails partly white, while *Lobiophasis* cocks have entirely white tails. Both are chestnut brown during their early stage. Secondary sexual characters are developed in *Lobiophasis* on the wattle and the tail, while the general color pattern is well developed in *Hierophasis*. All three groups have the same wing formula: 4th, 5th and 6th primaries being about equal and the longest. The cocks of *Delacourigallus* resemble *Hierophasis*, although their color pattern is not so well developed, and the hen is

amazingly similar to that sex in *Lobiophasis*. When the hens of these two genera are compared, they show no sufficient generic differences. The hen *Lobiophasis* has 14 pairs of tail feathers while *Delacourigallus* has only 6 to 8 pairs. (I have only a limited number of aviary specimens and some have damaged tails). This difference has not more than specific importance, because we know that *Crossoptilon* has different numbers of tail feathers according to species. *Lobiophasis* has a blue, naked face, while in *Delacourigallus* it is red. This is only a specific character among *Gallus*. The feathers on the crown are slightly elongated in the female *Delacourigallus*, but not forming a crest; *Lobiophasis* has a normally feathered crown.

One can see clearly that *Lobiophasis*, one of the most peculiarly developed of all pheasants, is fundamentally quite close to *Delacourigallus*.

Geographically speaking, *Delacourigallus* lives in Annam, and the two allied genera on islands, *Hierophasis* in Formosa and *Lobiophasis* in Borneo. It is not difficult, therefore, to suppose that *Delacourigallus* is prototypic, and the other two developed into a larger, more ornate, type in distant insular localities.

We are further able to trace the affinity of *Delacourigallus* to *Gennaesus* and are sure that both have derived from a common ancestor.

For the ever-growing number of ornithologists who now prefer to adopt wide genera, *Delacourigallus* can be considered a subgenus of the genus *Gennaesus*, as well as its other allies: *Hierophasis*, *Lobiophasis*, *Diardigallus*, *Lophura* and *Houppifer*.

The generic name is given in honor of Jean Delacour, the rediscoverer of the Edwards' pheasant and the discoverer of the Imperial pheasant, who has also propagated these two species in his aviaries and made them well known to us by distributing them among zoological gardens in many parts of the world. The two pheasants included under the new genus are extremely rare in the wild state.



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19.

Eastern Pacific Expeditions of the New York Zoological Society. XXVI.

Crabs of the Genus *Uca* from the West Coast of Central America.¹

JOCELYN CRANE

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New York Zoological Society.*

(Plates I-IX; Text-figures 1-8).

[This is the twenty-sixth of a series of papers dealing with the collections of the Eastern Pacific Expeditions of the New York Zoological Society made under the direction of Dr. William Beebe. The present paper is concerned with specimens taken on the *Arcturus* Oceanographic Expedition (1925), on the Eastern Pacific *Zaca* Expedition (1937-1938) and on a special trip made to the Pacific shores of Panama by the author in January and February, 1941. For data on localities and dates of the *Arcturus* and *Zaca* Expeditions, refer to *Zoologica*, Vol. 8, No. 1, pp. 1-32, and Vol. 23, No. 14, pp. 278-298.]

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I. INTRODUCTION.

The present study is based on three collections: It is the second paper in a series dealing with the brachyuran crabs of the Eastern Pacific *Zaca* Expedition.² In addition, an account is included of specimens which were taken by the author during January and February, 1941, on the Pacific coasts of Panama and the Canal Zone. Finally, a discussion is included of specimens referred by Boone (1927) to *Uca galapagensis* and *U. helleri*, since a reexamination shows that other species and fresh points of interest are involved.

¹ Contribution No. 628, Department of Tropical Research, New York Zoological Society.

² Previously published: Crane, 1940.

The collections comprise a total of 1,093 specimens, distributed among 27 species, of which 11 are apparently new to science. This wealth of material and the ecological observations which I was privileged to make in the field on both the *Zaca* and Panama trips, are such that considerable additions are made in this paper to our knowledge of habits, habitats and the phylogenetic relationships of the species. In the following pages all references to courtship, courtship coloration, copulation and shelter building are based on observations made at La Boca, Balboa, Canal Zone, at the mouth of the Canal, during the recent Panama trip, while reports on habitat, general habits and everyday color in life are from notes made during both the latter trip and the *Zaca* Expedition, on specimens observed and captured along the west coast from Mexico to Panama.

Certain hitherto disregarded physical characters have been found to be of taxonomic value, and while Miss Rathbun's invaluable monograph (1917) remains, as before, the foundation of any work on these species, the number of new forms in the present collection necessitated the making of a new key.

I wish to express my appreciation for aid in the preparation of this study to the following people: To Dr. William Beebe, Director of the Department of Tropical Research, for suggestions and criticism, and for granting me leave of absence to make special observations on *Uca* in Panama during the winter of 1941; to Mr. Templeton Crocker for the opportunity of collecting material while on a cruise of his yacht *Zaca*; to Dr. Waldo L. Schmitt of the United States National Museum for the loan of material, and for laboratory facilities during study trips to Washington; to Dr. Roy Miner of the American Museum of Natural History for the loan of material; to Dr. Herbert C. Clark of the Gorgas Memorial Laboratory, for laboratory facilities during my trip to Panama and to Mr. H. H. Evans for most valuable suggestions in regard to collecting grounds in Panama and the Canal Zone.

The drawings in the present paper are the painstaking work of Mr. James Butler (Text-figures 2-5) and Miss Janet Wilson (Text-figures 6-8).

II. SUMMARY OF IMPORTANT POINTS.

1. *Courtship*: The waving of the large claw by male fiddler crabs is without question primarily concerned with the attraction of females, at least during the breeding season, and only secondarily with the warning-off of crabs trespassing on a male's feeding range. The waving is only one manifestation, or step, in a definite courtship display or dance which varies so greatly with the species that individuals can be recognized at a distance by their characteristic motions. The other portions of the displays include raising of the body and stretching of the legs, various steps to one side or the other, revolutions, and special motions with the minor cheliped. All of these

motions show off the areas of most brilliant color to the best advantage: for example, the anterior (ventral) side of the merus of the first two or three pairs of ambulatories are usually brilliantly colored in courting males, contrasting to the colored areas elsewhere on the body; yet these areas show only when the chelipeds are outstretched in display; the same is true of the merus of the major cheliped. The display of twelve species was observed.

2. *Color Change*: Courting adult males, in contrast to other adult males, and, of course, to females and young, change color daily upon exposure to sunlight within the space of a short time—from a few minutes to an hour or more being required. The crab does not display vigorously and completely until full courtship color is assumed, the courting dress being always brighter than any other phase found in the same species. That courtship coloration and display play a definite part in sexual recognition and attraction is certain; that they play one also in sexual selection is likely, but has not yet been proved by experiment.

Courting males lose color rapidly when captured, resuming more or less completely the shades and patterns characteristic of the females and young, so that accurate color notes on breeding coloration can only be made when the crab is free and undisturbed. The use of binoculars in such study is almost essential.

3. *Mating*: Copulation was observed above ground, for the first time in natural surroundings, in three species. In each case it was preceded first by elaborate display of the male, and then by mutual stroking. The major cheliped played no part in actual copulation. It is thought that in most cases mating normally takes place below ground, but that when a female becomes acquiescent at the mouth of her burrow, which is usually too small for a male to enter, he induces her to mate there. When possible, however, he leads her, by means of display, to follow him down his hole. The latter procedure was observed in seven species. Even at the height of the breeding season, males are successful in only a minute fraction of their courtships, and then only after prolonged and much interrupted displaying which sometimes is protracted over a period of days. All the courtships were observed in Pacific Panama in late January and throughout February, in the midst of the dry season; ovigerous females were seen in all courting species. Whether breeding continues at other times of the year is not yet known.

4. *Shelter Building*: Shelters made of pellets of sand, roughly semispherical in shape, were built by courting males of certain species on certain days above the mouths of their burrows. The function of these structures remains as yet unexplained.

5. *Phylogeny*: A tentative phylogenetic tree of the species of *Uca* from the eastern Pacific is presented. Basic characters, including especially the mouthparts and minor chelipeds, have proved to be of more value in tracing relationships than



Text-figure 1.

Shore collecting stations of the Eastern Pacific Expeditions of the New York Zoological Society.

the characters usually employed to differentiate species, such as the form of the major cheliped, width of the front and convexity of the carapace. Related species show fundamental similarities in courtship displays as well as in physical attributes. Specialization has taken place in a number of directions, but especially toward provision for withstanding dryness, in connection with the adoption of a truly littoral existence. Species living, or at least courting, on shores which are daily exposed by the tide for relatively long periods in general have the most highly developed courtships and the brightest colors, including dazzling white, in contrast to forms living exclusively on briefly exposed mud flats.

6. *New Species*: Of the 27 species in the present

collection, 11 appear to be hitherto undescribed. This raises the total of apparently valid species known from the eastern Pacific from 22 to 33.

7. *Taxonomic Notes*: Miss Rathbun's synonymy (1917) has been followed throughout. The following forms, described or recorded since that date, should apparently be synonymized as indicated:

U. galapagensis, Boone, 1927 (not *U. galapagensis* Rathbun) *part.* = *U. macrodactyla* (Milne-Edwards & Lucas); *part.* = *U. panamensis* (Stimpson); *part.* correctly identified.

U. brevifrons var. *delicata* Maccagno, 1929. = *U. brevifrons* (Stimpson).

U. guayaquilensis Rathbun 1935. = *U. festae* Nobili 1902.

III. MATERIAL AND METHODS.

The data in the present paper are the result of two separate methods of working. The first, consisting of intensive collecting and of habitat observations from southern Mexico to Panama, was undertaken chiefly on the Eastern Pacific *Zaca* Expedition, from December, 1937, through March, 1938. Because of the nature of the trip, during which a maximum of a week or ten days was spent in each bay, and all groups of crabs were studied and collected without special reference to *Uca*, it was impossible to make prolonged and detailed observations of fiddler crab habits which by their nature require long daily periods of observation, preferably in the same locality. Therefore, during the five weeks spent in Panama during January and February of 1941, attention was directed primarily toward filling in the gaps in the *Zaca* habit notes, and only secondarily to collecting.

Observation in Panama was largely confined to one small area, a slightly brackish cove at La Boca, Balboa, Canal Zone, at the very mouth of the Canal. This locality proved to be so rich and was so accessible that it seemed wise to concentrate study here. However, colors and courtship displays were checked in other nearby places, including the mud flats at Bellavista, Panama City, and at Old Panama, a few miles south along the coast.

It was found that when the same area was visited day after day, and hours spent in observation, the activities of certain individual crabs could easily be watched for as much as four weeks at a time, individuals being differentiated by means of damaged or regenerated claws and legs, or scars on the carapace. Since many of the crabs at La Boca were, most fortunately, in the midst of courting at this time, and since my stay was definitely limited, it seemed best to make all observations on these crabs while they were in a completely natural condition, although there was a temptation to divide my time between that type of study and experiments in the field of sexual selection, to try to determine the actual extent, if any, of the effect of the male's color and display in his attraction of a mate. However, since controlled experiments to be at all significant would have required a great deal of time, it seemed better to reserve them for a later study, and to limit observation to natural reactions, particularly since this field is so little explored.

On both the *Zaca* Expedition and on the more recent trip, a pair of Number 7 Zeiss binoculars was constantly used. Although it is true that most species will overcome their fear after a few minutes and resume their activities more or less normally if an observer remains perfectly quiet close by, still the slightest motion sends them into their burrows again. On the other hand, after crabs watched through a binoculars at a distance of 12 or 15 feet have once emerged and lost their fear, it is possible to move slowly, make notes, and switch observation from one individual to

another without alarming any over a period of hours.

In photographing, a Leica camera was used with a 90 mm. telephoto lens at a distance of about 20 inches. The camera was attached to a focussing device, which in turn was screwed to a tilt-top tripod head. The latter was attached to a six-inch news-camera hand-holder. The handle was thrust through a square of cardboard as far as the tripod head, in order to protect the camera from sand, and then pushed into the muddy sand up to the cardboard. A pencil stuck into the ground beside the desired crab hole was used as a temporary focussing point. After the crab emerged it was often possible, if the first exposure was not made for several minutes, to release the shutter and wind the film for another picture without alarming the crab, provided that the movements of the fingers were exceedingly slow, and hidden as much as possible by the camera. In bright sunshine, on the dark gray muddy sand of La Boca, an exposure of 1/60 of a second at F16 on Eastman Super-XX film was found to give the most satisfactory compromise between speed and depth, although even this combination gave, of course, very little depth and yet would not stop the motion of the large claw when on a downward or upward swing. A series of these photographs was found to be valuable in showing the relative position of the various appendages at a given point in the display in the various species, and proved a most useful addition and check to repeated visual observations.

Methods of measurements and special terms used in the following pages should be defined thus:

1. *Length*. Measured from most anterior extension of front to posterior margin of carapace, in the longitudinal median line.
2. *Length of palm*. In either major or minor cheliped, measured from its most proximal origin on external side to the gape between the chelae, midway between lower base of dactyl and upper base of pollex.
3. *Base of palm to tip of pollex*. Measured from most proximal point of base of palm on external side to tip of pollex.
4. *Length of dactyl*. Measured from its origin on dorsal profile to its most distal projection.
5. *Width of front*. Measured between posterior margins of bases of eyestalks, as they appear when the eyes are lying flat in their sockets.
6. *Major side*. The side giving rise to the large or major cheliped.
7. *Minor side*. The side giving rise to the small or minor cheliped.
8. *Eyebrow*. As defined by Miss Rathbun (1917, p. 375); the intervening space between the two margins of the upper part of the orbit; it is usually broad, more or less inclined, roughly triangular.
9. *Suborbital region*. The area between the

lower border of the orbit and the pterygostomian region.

10. *Grooving of ischium of third maxillipeds.* This character is best examined with the appendage held out of liquid, and turned back and forth under a good lens in a strong, oblique light.

11. *Number of spoon-tipped hairs on second maxilliped.* Throughout the following study, where the number of spoon-tipped hairs is referred to, the count given is of those on the merus of the second maxilliped only; that is, those which occur on the tip of the palp are excluded. In those forms with most of the internal (upper) surface of the merus lined with these hairs, only those individual hairs are counted which project beyond the inner margin; the number of rows of hairs given, however, is always the total number. In all counts, hairs with rudimentary spooned tips are disregarded.

12. *Display.* The unit of behavior consisting of a single wave or gesture with the major cheliped along with its associated activities (stretching, running, "dancing," rapping, etc.). A number of displays following quickly upon one another, with little or no pause between, is termed a "series."

IV. ECOLOGY.

A. Habitat.

In general, the habitat of individual species is much restricted; some forms are found only in open sun on brackish salt mudflats, others in the deep shade among mangrove roots, still others on open muddy sand beaches, and so on. A given type of terrain may be expected to yield certain species; a similar but slightly different type only a few yards away, supports other forms. Some species, however, may inhabit more than one kind of environment. The great majority live in mud, either on protected tidal flats close to the mouths of streams, so that the water is somewhat brackish, or on the banks of sluggish streams of brackish water. Probably species originally migrated from this relatively stable, quiet environment to fresh water streams on the one hand and to open marine beaches on the other. The habitats of species in the present collection are as follows:

1. Muddy banks of fresh water streams (mostly shaded).

pygmaea
zacae
brevifrons
mordax
latimanus

2. Muddy banks of brackish streams (mostly shaded).

mordax
brevifrons
limicola
latimanus

3. White clay banks of brackish streams (mostly shaded).

argillicola

4. Mud, among mangroves (completely or partly shaded).

zacae
mordax
brevifrons
tomentosa
umbratila
inaequalis
tenuipedis
batuenta
crenulata

5. Mud, among unshaded mangrove shoots.

insignis
oerstedii
batuenta

6. Tidal mud flats (unshaded).

princeps
heteropleura
styliifera
insignis
macrodactyla
oerstedii
inaequalis (rarely)
saltianta
beebei (near beach)
galapagensis (?)
helleri (?)

7. Protected muddy-sand flats or beaches (unshaded).

princeps
heteropleura
styliifera
insignis
beebei
stenodactyla
deichmanni
latimanus
terpsichores

8. Marine sandy beaches, among stones.

panamensis

There is evidence (see page 170ff.) for the belief that *U. princeps*, *heteropleura* and *styliifera* spend most of their time on mud-flats, but come to adjacent sandy-mud beaches to court, since the added firmness of the ground would probably be a distinct aid to display.

La Boca: As an example of a particularly and surprisingly rich locality for the study of fiddler crabs, a small cove on the left bank of the Pacific mouth of the Canal is unsurpassed. This cove, lying between the Balboa docks and the La Boca ferry, and surrounded by piers, motor roads and the continuous traffic of the Canal, yielded 15 species of *Uca* in January and February, 1941, in an area not more than 600 feet square. The total number of individuals in this space must have run into the hundreds of thousands. Of these species, 12 were actively courting. The cove is entirely empty of water at low tide, exposing a mud flat and, bounding it on two sides, a narrow beach of muddy sand. At the inner end, the muddy sand is mixed with gravel, and adjoins a small clump of mangroves.

The third side, parallel to the Canal, is bounded by Pier No. 4, and the fourth side, facing the canal mouth and the ferry, is open. The water is slightly brackish, because of the overflow from the canal locks. The exceptional richness is probably due chiefly to the fact that a large sewer opens practically into the cove, and that garbage from ships is frequently washed up. The dissolved organic detritus from these sources must greatly enrich the tidal deposits on the mud. The fact that these 15 species taken included 5 hitherto undescribed (although all of them had been taken also on the *Zaca* Expedition, farther up the coast) shows how many valuable studies are waiting to be made in the tropics, even in the most accessible, thickly populated and apparently unlikely areas.

The extent to which more than one species occupies a given stretch of ground seems to depend entirely on the available space and the number of individuals it can support, provided of course that the terrain is equally suitable for the various species. At La Boca, for example, in one part of the beach *stenodactyla* was dominant, but mingled with numerous *beebei* and rare *styliifera*; farther down toward the mud, where the ground stayed more moist, were found *deichmanni*, *heteropleura*, and, dominantly, *beebei*. In the most protected part of the cove, most subject to dryness, behind the mangroves, *latimanus* was dominant, with only very few *terpsichores* intermingled; in the gravelly sand area, *beebei* was dominant, mingled with uncommon *terpsichores*. In less rich areas, the species tend to keep separate, there being definite boundaries, for example at Corinto, Nicaragua, between a large colony of *stenodactyla* and an equally large one of *styliifera* close by, on apparently identical terrain.

In crowded colonies, with the feeding ranges of individuals much restricted, there are of course many more provocations for fighting than in uncrowded areas, but it also seems that far more toleration has been developed in these individuals. Sex obviously is an important if not vital factor in argument. Adult males of different species and the same or different sizes will tolerate each other's burrows exceedingly close together: *beebei* and *stenodactyla* have been seen living day after day only one and a half inches apart, whereas adult males of the same species will tolerate each other's burrows not less than three inches apart and generally more. Females and young crowd closely, likewise, with practically no argument.

B. Burrows.

No special studies were made on the subject of burrow digging, except to determine average depths and forms for the various species. As was to be expected, species on yielding mud had the shallowest holes, and large species high up on relatively dry muddy sand beaches, or along the banks of drying streams, dug deepest. The burrows of individuals of the same species varied considerably, depending on their location and,

of course, on the size of the crab. The instinct of burrow-making seems least well developed in *panamensis*, which lives on the stone-strewn ends of sandy beaches. Very young crabs of all species do not dig, but run freely in and out of the burrows of adults, both of their own and different species, which pay no attention to the small ones whatever. For detailed accounts of burrow digging, consult especially Pearse (1912), Dembowski (1926) and Verwey (1930).

An interesting point is that *styliifera* and *beebei*, at least, often occupy their burrows for days and even weeks, without changing the location of the mouth by so much as half an inch. Contrary to Dembowski's observations on *pugilator* in captivity, in all the species observed the crab emerged after high tide, leaving the entire length of the burrow free, and frequently did not repair or change it at all from one day to the next. The crab must simply push its way through the sand in emerging, instead of digging himself out in such a way that a hole only the size of himself is left at the top, as seen by Dembowski.

Burrows are usually, but not always, plugged up before the tide covers them. Females and young, especially of *latimanus*, which lives at La Boca high on the shore, often plug their holes with a dome of pellets brought up from below for two or three hours around noon on especially hot, bright days; later, if the tide is still far out, they reemerge and resume feeding.

C. Feeding.

The general process of scooping up mud or sand with the spooned minor chelipeds, carrying it to the mouth, separating the organic particles by poorly-understood actions of the mouthparts and passing the remaining detritus out at the posterior end of the buccal cavity in the form of a pellet, has been too well stated previously to need repetition. The observations of Pearse (1912), Monod, and Verwey are the most detailed. The method by which the actual sifting is done remains as mysterious as ever.

Every species observed on the west coast definitely wiped or clipped off the pellet which formed at the posterior part of the buccal cavity after between 6 and 16 cheliped-fuls of sand or mud had been conveyed to the mouth, and carefully placed the pellet in front or to one side of the crab; the only exceptions were a few individuals observed starting to feed while there was still some water on a mudflat as the tide was going out; in these cases the water dissolved and carried away the rejected mud. Matthew's statement that *U. leptodactyla* on the coast of Brazil picked up separate organic particles from the ground is most interesting; it seems likely that there was an error made in observation; the same is almost certainly true, as Verwey has contended, of Symon's statement that the rejected mud passed out at the *front* of the buccal cavity. Altogether, I have watched at least 20 species of *Uca* actually feeding, and in all the process is identical, save for three exceptions. The first, that of *Uca's* feeding with the mud

slightly underwater, has been noted; the second was that of four individuals of *brevifrons* seen feeding on mammalian excrement on the bank of a fresh-water stream, several miles from the coast, at Port Parker, Costa Rica; the third is the practice of *panamensis* of frequently climbing upon rocks and scraping off the algae for food with its small cheliped, just as do *Pachygrapsus transversus*, *Grapsus grapsus*, and others. Both *brevifrons* and *panamensis*, however, also feed in the usual fashion of fiddler crabs. Although there are doubtless exceptions, like the *brevifrons* mentioned above, and those noted by Pearse (1912), fiddlers as a general rule are certainly not scavengers: a number of times I have seen garbage, dead fish, or a dead bird in all stages of freshness and decomposition washed up in a colony of fiddlers and lying untouched in their midst, although normally nocturnal hermit crabs were swarming over it.

The roles played by the various types of minor chelae and the various numbers of spooned and wooly hairs on the second maxillipeds are unknown; they will be further discussed on pages 161 to 165.

D. Fighting.

The conclusions of most other observers were verified that, although brief duels, in which the large chelae are interlocked, are frequent, injury is exceedingly rare. I have only once seen any dismemberment actually take place, and this was the extreme tip of a dactyl. However, the frequent sight of crabs with similarly or further damaged chelae indicates that such mishaps do occur now and then, although, of course, it is possible that they can also occur in other ways, such as by being broken on a stone against the side of the burrow, or in escaping from an enemy.

A definite duelling ritual was followed in all except cases of extreme provocation, such as pursuit of the same female in *U. stenodactyla*, in which there was no time for preliminaries. Usually, however, a duel proceeded as follows: Only infrequently was a duel preceded by display,—i. e., by rhythmic series of beckonings—and then never by vigorous display such as was used in courting a female. Instead, the combatants first prance toward each other, stiff-legged, patting the ground with the bottom of the great palms and claws, as though in challenge. Then both lunge and feint a few times, with the back and sides of the semi-flexed chelipeds, which meet in audible clicks. At last, after several or half a dozen such parries, they proceed to the last step and interlock claws. This last movement is always undertaken warily, since there is always danger that the nipper may be damaged or wrenched off. Then, the claws locked, the crabs lunge in turn, pushing each other back and forth, first one and then the other sinking down and back until his shell often actually touches the ground. Usually this continues until the weaker breaks away and runs for his hole; occasionally he is somersaulted backward with a flip of his opponent's claw; often the larger simply stops

fighting and moves off without there being any decision. Most duels last only a few seconds; the record was 25 minutes (see p. 160). Sometimes, as has been observed by others, the weaker is pushed down his own hole, where he uses his large claw to stop up the opening, for a few minutes, apparently to prevent the entry of his antagonist.

The provocation for a fight is usually either poaching on the territory of another male, or courting of the same female. Sometimes, however, there is no stimulus apparent for the most spirited encounters; until some better explanation is found, these must be laid to sheer excess energy, probably associated with the condition of the glands in the breeding season, or may simply be termed sport (see p. 159).

E. Crippled Crabs.

Several instances have been observed where crabs with badly damaged chelae, with the cheliped completely missing, or with more than two ambulatories missing, were definitely bullied by other crabs. In each of these cases the cripple was repeatedly driven down his hole by one of his neighbors. Once a normal male *U. beebei* kept watch for at least several hours over an injured neighbor, the burrow of which was a foot away, well beyond the feeding ground of the normal crab. Every time the cripple emerged the neighbor would stop his own feeding or courting, run over and struggle until the cripple retired to his hole, after which the normal crab would push sand in after him and stamp it down until no trace of the burrow was left. Each time the cripple emerged the routine was repeated. No attempt appeared to be made actually to harm the crab or to follow him down his hole.

Many crabs with claws in various stages of regeneration, however, seemed to carry on completely normal lives. Twice I have seen crabs with the *minor* cheliped missing which were eating awkwardly, but with apparent success, with the major cheliped. I have not yet observed a male without the major cheliped temporarily mistaken for a female as described by Verwey. For a case of a male courting with a half-regenerated claw, see p. 155.

F. Display, Coloration and Shelter-Building: Their Relation to Courtship.

For more than a hundred years the sexual dimorphism of fiddler crabs, the function of the waving of the large claw in the air, the frequently brilliant color of the large claw and the possible significance of all these factors in regard to sexual selection, have become matters of increasing interest and controversy to students both of crustacea and of general evolution. The opinions of the principal workers in the field may be briefly summarized as follows: The earliest—Müller (1869, 1881), Darwin (1871) and Alcock (1892, 1902)—were convinced that both waving and bright colors played a definite part in courtship, that females recognized males in this fashion

and appreciated the display, which gave to color and activity a vital role in sexual selection. Pearse (1912, 1914.1, 1914.2) accepted the conclusion that the males danced around the females in order to attract their attention, but was not convinced that the females were thus attracted, or that the colors had anything to do with sexual selection. Symons (1920), Johnson & Snook (1927), Beebe (1928) and Matthews (1930) added brief observations on various species which showed that males were sometimes definitely stimulated by females to increased waving activity and special behavior. And, finally, Verwey (1930) and Hediger (1933, 1934) denied that the waving had anything whatever to do with courtship, declaring that it was carried on instead solely to designate the possession of a hole, and limitation of the surrounding feeding area.

After concentrated observation in Panama during the breeding season of a dozen species living in a single restricted area, I am convinced that the truth lies somewhere near the middle of these extremes of conflicting opinions. Waving, as in other crabs, is certainly carried on some of the time as a warning to other males and to delimit territory in some (but not in all) species of *Uca*. On the other hand, in many, if not in all species, waving definitely plays a large part in courtship and, in one species at least (*latimanus*), is apparently carried on only by courting males.

In regard to the importance of color in waving, I cannot draw definite conclusions until further studies have been carried out. These must include experiments in artificial coloration as well as many more observations on the natural behavior of the crabs. However, it seems certain that color and motion are correlated in display, although color is perhaps the less important of the two aspects. This subject will be further discussed later (pp. 154 to 159).

Display Activity: A comparison of the observations of the authorities listed above shows that among different species there are certain variations in the activities accompanying waving. Studies on Philippine fiddlers by Pearse (1912) show that in one or more species the males dance around the female, showing only their backs to her, so that the great chelae could not be seen by the females, which usually paid no attention to the males in any case. Sometimes the males held statuesque poses, the chelipeds upraised or outspread for minutes at a time; the females often were, surprisingly, more brightly colored than males of their own species. Pearse states, however, that his observations were not made during the breeding season, and season should doubtless be held a most important factor in all studies of display and coloration among these crabs.

Alcock, reporting on *annulipes* in Ceylon, Symons on an unidentified *Uca* on the same island, Johnson & Snook on *crenulata* in California and Matthews on *leptodactyla* in Brazil, all reported that the males of these particular species were galvanized to more active waving

by the appearance or presence of females. Johnson & Snook stated definitely that this reaction took place during the breeding season, and that crabs did not wave in captivity, although they carried on all other normal daily activities.

Beebe, observing *mordax* in Haiti, found that certain females stimulated the males to intensified waving, which consisted of "a beckoning in five jerks, the last of which almost threw the crab over on its back; the difference between this gesture of the right hand of passionate fellowship and that of shaking the fist in the face of any passing male was hardly to be discerned. In the case of courtship the fiddler would often freeze into a statuesque pose for three or four minutes at a time."

Swartze & Safir observing *pugilator* in Massachusetts, and Hediger studying *tangeri* in Morocco, agreed that the crabs waved at the rate of once every two seconds; *pugilator* varied simple waving with statuesque poses according to Pearse (1914.1) such as those in *mordax* and some of the Philippine crabs (Pearse, 1912). Hediger mentions no posing in *tangeri*, however, but refers to the elevation of the whole body which sometimes accompanies beckoning.

Verwey, in his study of *Uca* in Java, reported that *signata* in waving, stretched high up and sank back, sometimes shaking all over. This species, according to the same author, when captured as well as when in the field, waved threateningly at both males and females, though apparently not so forcefully at the latter sex. Although Verwey witnessed no copulations, he saw males approach and cover females from behind, giving the females no opportunity to recognize, much less be attracted, by the male in question. He was apparently present during the breeding season, since he has a number of records concerning the abundance of ovigerous females on various dates.

The observations summarized above show that waving, whether or not the observer admits its being used in courtship, is often accompanied or varied by the following activities: (1) by statuesque posing with the arm outstretched or upraised, (2) by shaking of the entire body, (3) by elevation of the body with each beckoning gesture, (4) by "dancing" around the females, and (5) by increase of tempo in the presence of females.

My own observations show that the last characteristic of accelerated waving is the only one which is characteristic of most species in display. In Panama, each of the species studied combined with waving variations of one or more of these five and other activities. In fact, each species proved to have a definite, individual display, differing so markedly from that of every other species observed, that closely related species could be recognized at a distance merely by the form of the display. Furthermore, related species had fundamental similarities of display in common, and series of species, showing progressive specialization

of structure, in general showed similar progression in display.

At La Boca, Balboa, Canal Zone, the courtships of twelve species were studied in considerable detail. These twelve are divided into three groups, each composed of more or less closely related species. The first ("Group 1," p. 165) consists of *princeps*, *heteropleura* and *stylifera*; the second ("Group 4," p. 166) of *oerstedii*, *inaequalis*, *batuenta* and *saltilanta*; the third ("Group 5," p. 166) of *beebei*, *stenodactyla*, *deichmanni*, *latimanus* and *terpsichores*. In this last group the first two and the last three form definite subgroups.

The display of a thirteenth species, *panamensis*, was seen only once, and on this occasion the crabs were apparently not displaying fully; hence it is omitted from this summary, but described on p. 204.

The basic element in all fiddler display is, of course, "waving" or "beckoning" with the major cheliped. In its simplest form this consists of unflexing the manus and chelae from the resting position in front of the mouth, by movements of the ischium, merus, and, perhaps, carpus, which elevate the distal elements diagonally over the head; they are usually lowered at once, without a pause, often with a jerk, in the same plane to the original position. The variations of this simple beckoning gesture and its accompaniments in the twelve species listed above are as follows:

1. *Beckoning or Waving*: a. Three of the four crabs of the second group hold in common a special sort of cheliped motion: After the usual beckoning, the cheliped is brought to the ground, flexed, more or less in front of its usual rest position, and is then bounced back into place with three or four raps of the ground; this additional action is added to the regular display occasionally in *inaequalis*, often in *batuenta* and always in *saltilanta*. In the latter species the cheliped is bounced vigorously almost in place, since only rarely does it fall in front of its normal rest position. In physical characteristics also these three species show progressively greater specialization.

b. *U. deichmanni* holds the cheliped for an instant at the highest point of its reach, then lowers it into position and raises it again without a pause, so that the accent comes at the peak of its stretch, instead of in the flexed rest position.

c. *U. latimanus* makes a somewhat circular gesture in beckoning. To a lesser degree this is occasionally true of other species.

d. *U. terpsichores* starts display with the manus and dactyl of the large cheliped half unflexed, pointing straight out in front of the crab.

e. The rate of display when the crab is not specially excited varies among species from two or more gestures to the second with no pause between them (*saltilanta*, *beebei*, *deichmanni* and *terpsichores*) to one and a half to three seconds being required for every display, including both the gesture and the pause following it (*princeps*, *oerstedii*, *inaequalis*). Both slow and fast displays

occur in all groups, without relation to the degree of specialization.

Usually a more or less definite number of displays is made in a series when a given species is displaying fully, each series being followed by a rest of seconds or minutes. The most tireless so far observed is *saltilanta*, which frequently displays, at the rate of two gestures to the second, for upwards of one hundred at a time without an instant's pause. After a rest of several seconds another equally long series will be commenced, and the procedure may continue, without interruption for true rest or feeding, for at least an hour. On the other hand, in every species display is often casual, half-hearted and punctuated by feeding.

2. *Elevation of Body during Beckoning*: As in *tangeri*, the body is elevated and depressed during each beckoning by *princeps*, *heteropleura*, *stylifera* (sometimes), *inaequalis*, *batuenta*, *saltilanta* and *deichmanni*. The other five species hold it consistently high during a series of displays. In elevation, the crab stretches to tip-toe with the raising of the cheliped, and sinks into position when it is lowered. *U. heteropleura* carries this habit to the greatest extreme, stretching so high that only the tips of the two middle pairs of ambulatories remain on the ground. *U. stylifera* sometimes stretches the two front ambulatories, elevating the anterior part of the carapace, and simultaneously flexing the posterior legs, so that the rear part of the body is lowered during a display; this variation does not depend on the added stimulus of a female, but may be inserted in the midst of a series of displays, or an entire inter-tidal period may be devoted to this variety. Species which elevate and depress the carapace during each display occur in all three groups.

3. *Position of Chelae*: The chelae of both major and minor chelipeds are usually held slightly open and parallel during a series of displays; sometimes, however (especially in *batuenta* and *saltilanta*) they are opened and closed with every display—opening wide on the upward swing of the large cheliped and closing on its descent.

4. *Motion of Minor Cheliped*: Often the minor cheliped is moved in a feeble imitation of the beckoning or outward spreading of that of the major. This is generally true of *princeps*, *heteropleura*, and *terpsichores*, and true under conditions of excitement in other species.

5. Some species remain in one spot during display, notably *heteropleura*, which stretches up on its two middle pairs of ambulatories. More, however, usually take several steps to one side or the other with each elevation of the cheliped; in a given series of displays, they usually move several times in the same direction, then back to the starting point beside the hole; or with one gesture they may move to the right, with the next to the left. There is considerable leeway of behavior within a species in this activity, and individuals show similar variation in their behavior from hour to hour or day to day. *U. oerstedii* tends to move right around its hole, facing always outward, when the attention of a

female is not involved, during a series of displays. In the highly specialized courtship of *stenodactyla*, the males chase the females with the arm outstretched, motionless, or held overhead. If they can manage to approach a female closely enough, they surround her loosely with the cheliped, and race with her over the beach, apparently trying to maneuver her to their holes (for details see p. 196).

6. *Revolution*: The only instances I saw of a crab dancing with his back to a female were all performed by individuals of a single species, *beebei*. In this crab the anterior part of the carapace is a brilliant iridescent green, the cheliped chiefly rose, ochre and plum-colored, the anterior parts of the ambulatory meri magenta. Males of this species in a number of cases almost always revolved before females whose attention they had captured. The color of the carapace in this relatively dull form was certainly to human eyes at least as striking as that of the cheliped, and the combination most effective.

7. *Special Effects Reserved for Later Stages of Courtship*: The usual acceleration in tempo of display during active courtship of interested or potentially interested females has already been noted. In addition, special actions, highly characteristic specifically, may be observed in the later stages of courtship. Probably many more will be added to the following list when the complete courtship of each species is known.

a. *U. oerstedii*, when actively courting a female, vibrates the brilliant blue anterior ambulatories when the chelipeds are outstretched.

b. *U. saltitanta*, when convinced that a female is ready to follow him down his burrow, pauses halfway down its mouth, extends the ambulatories of the major side rigidly in the air and vibrates them rapidly.

c. *U. latimanus* vibrates the minor cheliped rapidly when displaying before an interested female. *U. stenodactyla*, when pursuing a female, extends this appendage stiffly outward, the chelae wide open, corresponding roughly to the gesture made with the large cheliped at this time.

d. *U. terpsichores* sometimes adopts the statuette pose previously noted in Philippine species (Pearse, 1912), in *pugilator* (Pearse, 1914.1) and *mordax* (Beebe, 1928), standing before a female for seconds at a time with the major cheliped spread out rigidly sideways; this pose in the present species is never held longer than a minute. *U. stenodactyla* extends the major cheliped similarly, either sideways or upward, when chasing females.

e. Special steps with the ambulatories, giving the effect of a definite dance, are taken in the last stages of courtship by two quite unrelated species, *styliifera* and *terpsichores*.

f. Mutual stroking of legs and carapaces with the ambulatories by both male and female took place in the final part of courtship in all three species in which copulation was observed, namely *styliifera*, *beebei* and *stenodactyla*. In each case the male instigated the stroking and was by far the more active partner.

8. *Use of Special Display Ground*: All species, when courting, in general kept the ground surrounding their holes well packed down and free of feeding pellets, but *saltitanta*, which lives and displays on the stickiest, dampest mud flats, whenever possible mounts to the summit of a nearby elevation, sometimes a dozen times his own height, in order to display.

9. Although particular attention was given, no hint was seen of the use of antennae, ocular stylets (in *heteropleura* and *styliifera*) or of stridulating ridges (in *terpsichores* and allies) in display.

Coloration: As has been repeatedly noticed, the adult males in the genus *Uca* are frequently brilliantly colored, especially in regard to their large cheliped. The females and young on the other hand are relatively dull, being usually brown or gray, often spotted or mottled with darker or lighter. Pearse (1912) alone has remarked that "at Manila the female fiddlers often were, to the human eye, more brightly colored than males of their own species, and the female's bright colors were on her back and legs so that they could readily be seen by a male dancing behind her, but *she* did no dancing." As the author remarked, his observations were not made during the breeding season.

Müller, observing a species of *Uca* in Brazil, was apparently the first to notice color change in the field, of which no further accounts seem to have appeared until the present study.³ His summary (1881, p. 472) is as follows: "When it (the fiddler) runs from its moist burrow into the sunlight the entire splendor of its nuptial clothes develops; as soon as one catches it, the pure white, the light green, which decorate its claws, begin to lose their luster and change in a few minutes into uniform gray." The present author, unfamiliar with the above reference when making observations in Panama, found exactly similar

³The interesting observations made on Atlantic fiddler crabs from which the eyestalks have been removed are not directly relevant to the present study, since all were made under extremely unnatural laboratory conditions. The most recent summary (1940) of Abramowitz & Abramowitz indicates that eyestalk removal brings about loss of pigment, accelerates moulting, increases the death-rate in moulting and results in gigantism. The authors also insert the following remarks (p. 187) without further elaboration, regarding the breeding of *U. pugilator* in captivity: "*Uca* breeds during September, as indicated by the appearance of large masses of eggs, copulation and final shedding of the eggs. Animals without eyestalks have been observed to copulate and shed their eggs. However, such animals were blinded for only a few weeks before the onset of the breeding season, and thus sufficient time may not have elapsed for any effect on reproduction to take place. This is worth investigation, however, for as yet no endocrine influence on the reproductive system of crustaceans has been demonstrated." Brown concluded (1940) that the source of the chromatophorotropic substance of the crustacean eyestalk, including that of *Uca*, is the sinus gland. Kleinholz & Bourquin (1941), however, state that not all of the conclusions of the above-mentioned investigators are yet proved, due to various details of the technique employed in the experiments, and of laboratory conditions involved.

conditions in all of the crabs which were known to be courting. Two of the most striking illustrations will be summarized here and are typical of the rest.

Only adult males and females of *styliifera* were found on the relatively firm muddy sand shore above the mud flats at La Boca. They occurred there in increasing numbers throughout February, and it seemed likely that they migrated from the soft, damp flats to court on the dryer ground. (*U. saltitanta* and others, however, manage to keep clean and carry on a strenuous display in the midst of the mud-flats.) Courting males of *styliifera*, after emergence in the morning, changed from dull gray with the major cheliped chiefly brownish or yellowish, to pure white with the major cheliped orange, yellow, pink and white and the ambulatories bright purple. There was a brief intermediate phase where the carapace was brilliant yellow instead of white. It appeared that for the first one to three days an individual male was on the beach, and before he was displaying fully, the carapace brightened daily only to this yellow phase.

A male *styliifera* which coaxed a female, after prolonged courtship, to follow him down his hole, promptly enlarged it, then stopped it up with both of them inside, and remained with her there until the following low tide. The next day the male was in poor coloration and did not display. The female had vanished.

The courtship of a male of this species with the major cheliped in process of regeneration and only half size was observed throughout three weeks. Although otherwise normally colored—with dazzling white carapace and the legs purple—the regenerated member changed daily from drab gray brown to perfectly white, like the carapace, instead of yellow, orange and pink. This individual courted two females impartially for days until one moved away; he then paid all his attention to the other; I never saw copulation take place, nor saw either female attracted to his hole, but both often allowed him to approach and stroke them at the edges of their holes. I never, however, saw them stroke him in return, as in a consummated courtship between a normal male and female. For further details concerning this species, see p. 171.

The other most striking example of color change occurred in *latimanus*. The females, young and non-courting males, no matter how large, as well as males newly emerged from their holes after high tide, were similarly colored, the carapace being brown with gold spots and the ambulatories brown banded with dark; in the case of the males the large cheliped was dull chestnut brown. In these crabs it was a stricter rule than in any other species that only displaying males changed color daily, and conversely that all males which changed color displayed; finally, all of these and only these, built shelters (see p. 157). In the displaying males, the carapace each day, after feeding, during shelter building, and before display started, became pure white, the major cheliped chiefly bright orange, and the anterior sides of the ambulatory meri plum red.

In this species the display-color-change-building cycle was definitely under tidal influence. When first observed, on the last three days of January and the first two of February, during the spring tides of new moon, practically all the males high on the beach, with holes covered with water only during the highest tides, were displaying, while none of those lower down were doing anything save feeding and repairing their holes. Among this latter group not so much as a single waving movement was seen, although full grown males were as numerous as near the high water line. Similarly, in contrast to the upper group, males and females paid no attention to each other and I did not see a single fight go beyond the stage where the owner of a hole moved menacingly toward a trespasser, his cheliped thrust forward, *without warning*; in each of these few cases the threatened crab moved off promptly. In the following days of neap tides, when the water did not reach the upper part of the beach, the members of the upper colony remained in their burrows, six inches to a foot underground, for eight days (February 3-11). When dug up they appeared to be in a partial coma, and did not try to escape for half an hour or more. During the succeeding spring tides of full moon these upper colony crabs reemerged, repaired their burrows and fed, but only a single individual on a single day displayed, changed color and built a shelter during the entire period. They again remained in their burrows during neap tide, reemerging during new moon around February 25. Again there was no display. On the lower part of the beach, at this new moon period, however, a wave of display, color change, shelter building, mutual interest between the sexes and duelling, swept over the colony, exactly as it had four weeks previously higher on the beach. Observation unfortunately had to stop while this second courting wave was at its height. No actual copulations were seen, but several times females were observed to follow males down their holes, after watching long displays, and many more abortive courtships were observed, in which the female lost interest and moved away. (See also p. 157.)

In both these species, *styliifera* and *latimanus*, as well as in the others which changed less spectacularly, the display coloration was swiftly lost when the crabs were captured. The time required daily for the assumption of courtship coloration varied in different individuals and, to a lesser extent, in the same individuals on different days. One of the swiftest to change after emergence in the morning was *styliifera* which, on brilliant days, became fully colored within 15 minutes or less; one of the slowest was *latimanus*, which sometimes required two hours or more. The slowness is probably explained by the fact that *latimanus* always built a shelter before displaying, which necessitated its coming in contact with the damp sand and, apparently, dryness and sunlight are almost equally important in effecting color change; however, no experiments have as yet been conducted on this subject. Females, young, and non-courting males also brighten somewhat after emergence, but the

brightening consists only of emphasis of the prevailing drab colors, and is probably due as much to drying off as to exposure to light.

One of the most interesting aspects of display is the fact that ten of the twelve species studied show brilliant colors on the anterior side of the merus of the first three pairs of ambulatories, areas which can be seen only when the chelipeds are widespread in display. Another point has already been mentioned, namely, that in *beebei*, a relatively dull-colored form, almost the brightest portion is its iridescent green carapace: this species alone was observed to revolve in front of the female before which it was displaying; it is noteworthy that the ambulatory meri were as brilliant posteriorly as anteriorly.

The display coloration of the males of various species as far as known may be simplified and summarized in the following table. For the species in each group refer to pp. 165ff.

Courtship Color	Group 1	Group 4	Group 5
Carapace	Gray or white	Purple, brown-and-white or white	a. Iridescent green, or iridescent blue and white b. Gray or white
Cheliped	Purple, orange, yellow and white in each	Purple-and-blue, brown-and-white, or white	a. Purple-and ochre or pink-and-white b. Each many shaded, orange through magenta
Ambulatories	Gray or purple	Purple-and-blue, brown-and-white or white	a. Gray or red b. Gray or white
Anterior side of ambulatory meri	Major side salmon orange, minor side white	Peacock blue, purple, pinkish, white	a. Purple-and white, or scarlet b. Yellowish, plum red, white
Buccal & pterygostomian regions	White	Turquoise, brown, white	a. Green-brown, white b. Blue-and-green or white

Group 1 is, in regard to color as in physical form, the most homogeneous; the other two vary considerably in the different species. No group is characterized by colors specially confined to them. One of the most outstanding traits of coloration is the prevalence of white carapaces, which are found in all three groups, in a total of six species, although one of these six has the anterior portion bright blue. Often these species go through a phase of bright or dull yellow, or of ochre-streaks, before assuming the pure white. The phase before the yellow is usually dull gray. The gray carapaces found in *princeps* and *deichmanni*, the close relations of which display in white, may be evidence of relatively low development of color in these two species, corresponding to their relative lack of specialization within their respective groups. Possibly, however, none of the numerous specimens observed displaying was in full coloration: the examples of *princeps* were all small, around 15 mm. in length, although they acted in every way like adults.

In the twelve species studied it is interesting that the most highly specialized forms in each group—e. g. *stylifera*, *saltitanta*, *stenodactyla*, *lati-*

manus and *terpsichores*—have the most arresting coloration, in which dazzling white plays an important part: in all except *stenodactyla*, which is brilliant blue in front, white or pinkish-white behind, the carapace is completely white, *terpsichores* is white except for the cheliped, and *saltitanta* is altogether white. (It is in the two latter species alone that the anterior ambulatory meri are not specially colored.) In all of the above species, too, the displays are more highly organized.

Copulation: Actual copulation was observed in *stylifera*, *beebei* and *stenodactyla*, a total of five times. In each case it was similar, taking place at the mouth of the female's hole after a more or less prolonged and intense display which sometimes, apparently, lasted for days between the same two individuals, subject to innumerable interruptions by the hesitation and frequent withdrawal of the females as much as by alarms

from birds. Each copulation witnessed was preceded by mutual stroking of the legs and carapace with the ambulatories. The position was exactly similar to that illustrated by Pearse (1914.1) for *pugilator* in the laboratory. The two crabs faced each other, sternum to sternum, abdomens bent back, that of the male inside that of the female, the anterior ambulatories of each grasping each other around the body, the female with her posterior three pairs on the ground, supporting most of the weight of both. The chelipeds of the male rested above the female, the minor lying lightly on her carapace behind, or sometimes on top of, her eye, the major always clearing carapace and eyes, held flexed and perfectly quiet. The two remained together, quivering at first then quiet, for a very short time, up to three minutes; then the female would very gently disengage herself and slip down her hole, which she soon closed up, regardless of the position of the tide. In at least one instance, the male definitely stood guard over it afterward and warned off other males, *without* waving the cheliped rhythmically.

In *heteropleura*, *stylifera*, *saltitanta*, *beebei*, *stenodactyla*, *latimanus* and *terpsichores*, females

were seen to follow males, after vigorous display, down the holes of the males, remaining for anywhere from a few seconds to at least until the next low tide, since they did not emerge before the tide covered the holes. Always, during courtship, the male appeared to employ inexhaustible patience and gentleness except in two cases involving *princeps*, when two males of this species, on different dates, displayed briefly, then crept up on indifferent females from behind and tried, unsuccessfully, to drag them over to their (the males') holes.

It is probable that copulation usually takes place in the burrow of the male, but that when the female has been brought to the proper pitch of excitement at the mouth of her own hole, copulation takes place there, since her burrow is usually too small in diameter to receive the male. Provision for safety from birds and lack of interruption would seem to encourage copulation in the hole of the male, but the difficulty experienced by the males in arousing the females would explain the occasional surface pairings.

Pearse's observation that copulating females are hard-shelled was supported by my own observations. For further details of pairing, see below and pp. 173, 193, 196.

Shelter Building: In 1873 Verrill reported that specimens of *minax* built "ovens" above their holes. Matthews, working in Brazil on *leptodactyla*, made a similar observation. He described the method of building very accurately, his observations checking with my own made in Panama on *beebei*, *latimanus* and *terpsichores*. He attributed to the "hoods," however, the function of keeping the burrows from drying out in the hot sun. Whatever their function—which I have not yet discovered—it cannot be this, for it is *only* courting males that build shelters; the shorter burrows of the smaller females and young surely need protection far more than those of large males, yet this device is never used by them; instead, when the sun becomes too hot for them they use a simple plug to close their burrows, or push up material from below.

Of the three Pacific forms which were seen to build shelters, the instinct is least developed in *beebei*, best in *terpsichores*. In the first case the form of the shelters varies from little more than a pillar of sand beside the hole to a fairly well arched hood, little higher than the builder; also, it is not built by all displaying males, and is not necessary to win a female, since in the case of one of the two copulations witnessed in this species, the male had no shelter; in the other there was a well built shelter which played no apparent part in courtship. In *latimanus* a well formed shelter is always built by every displaying male. In *terpsichores* on the other hand the shelter is the best formed of all, and relatively the largest, but it is not built by every displaying male; however, the breeding season was waxing in this species when I left, and increasing numbers of shelters were being built every day. Incidentally, *terpsichores* and *latimanus* are closely related, and *beebei* more distantly, but all belong to the

same group of highly specialized crabs, all of which are adapted for life on relatively firm, dry ground. Only *beebei* occurs on mud-flats as well as on muddy-sand beaches; in the mud-living individuals, the building of shelters is more spasmodic and unsuccessful than ever; the very nature of the semi-liquid mud would make the erection of a well-arched shelter almost an impossibility.

This mysterious habit of building is probably a special development of the practice of stopping up the hole with a plug before the tide covers it. (Incidentally, this latter practice in the Pacific species studied is very casual, being rather frequently omitted by individuals in each species without any apparent reason). In making the shelter, as in plugging up the hole, the legs of the major side are used in scraping up and carrying the sand, and patting it into place, the crab always working from the underside of the growing half-dome. This method is in direct contrast to that employed in hole digging, when the minor side is invariably employed. It would seem that there is a distinct waste of effort when the crab, as often happens, first repairs his burrow, dumping the loads of sand several inches from the hole, and then builds the shelter, scraping the sand from a similar distance, but never using excavated, already loosened, damp sand for this purpose. The separate origin of the two activities explains this lack of correlation. For further details on the building activities of the several species see pp. 194, 203. On p. 196 is an account of equally inexplicable wall-building in mature females of *stenodactyla*.

Behavior of Females during Courtship: As has been said, the role of the female, until the final stages of courtship, is one of complete indifference or definite retreat. Each male must display for long periods daily in the hope of attracting the attention of a single female sufficiently to make her pause in eating or passing, and watch him. Once this is accomplished, courtship may proceed a dozen times a day to the point where copulation is about to take place, only to have the approach of a bird, or, even more frequently, the recurrent withdrawal of the female—often accompanied by the abnormally early plugging of her hole for the day—interrupt the courtship. The latter is resumed only after a repetition of lengthy preliminaries. In the cases observed where females either followed males down their holes, or mated with them on the surface, the successful male was sometimes only moderately large and brightly colored, compared with the most spectacular in size and color of the same species.

How females, all so similarly formed and inconspicuously colored, are recognized by males of their own species in mixed and crowded colonies remains a major mystery. Beebe observed a phenomenon in *mordax* which was also frequently apparent in various species in Panama, namely that a particular female often had the power to stimulate any number of males to violent display, merely by ceasing for an instant

to feed, or by emerging from her hole, or wandering a few inches from her usual position, whereas other individuals, equally large and of identical coloration, attracted little or no attention from the same males at the same time. For the behavior of *stenodactyla* when pursued by males, see p. 196.

Origin of Display and Comparison: Little work has been done on courtship and mating in other groups of crabs. The principal study is that by Chidester (1911), who found that sex discrimination is tactual in *Callinectes*, *Cancer*, *Carcinus* and *Platyonychus*. In *Uca* it is certainly not tactual, but instead largely or completely visual. As in Chidester's examples, however, once a female has permitted a male to touch her—except in the case of females pursued and encircled by male *stenodactyla*—the female is not passive in the movements preceding copulation.

Hediger (1934), although he does not think that waving of the large cheliped has anything to do with courtship, nevertheless presents a most sensible theory of its origin: "It is clear that the lifting of the chelae originated as a preparatory fighting motion (compare with other crabs), which as in many other cases, became only a threatening gesture, then was developed and transformed in this group into the signalling motion."

From my own observations, it appears that waving may be carried on throughout the year by many species of fiddlers, especially, perhaps, by the less highly specialized forms, as a purely threatening gesture, warning encroaching crabs away from a chosen feeding ground surrounding the hole. This type of display is relatively phlegmatic—unless an actual fight is imminent—and is often carried on with a perfunctory air while the minor cheliped is engaged in feeding. During the breeding season, however, the tempo of waving is greatly accelerated, and the activity is now devoted chiefly to the end of attracting females. Slow-waving-*cum*-feeding periods still occur at this time, a habit which obviously enables a crab to advertise himself to females which might pass him unnoticed, if he did not wave while he ate. The function of waving in warning off males at this time also seems definitely connected with courtship in most cases, since the females in a given territory are perhaps more or less consciously preëempted by the male. At least during the breeding season, when most of my observations were made, no male was ever seen to attack any except adult or nearly adult males; females and young came and went as they pleased, and there was far greater toleration between males of different species than between those of the same kind. Also, in a number of forms—especially in *stenodactyla*—females have been seen very definitely to be the cause of duels between males.

The conclusions of Verwey and Hediger, that waving has nothing to do with courtship, may be explained by the fact that courtship display may prove to be poorly developed in *signata* and *tangeri*, while their property sense is strong. On

the other hand, it may be that neither of these observers witnessed actual courtships in mid-breeding season. The latter explanation is perfectly possible, even though Verwey, at least, must have spent a great deal of time in observation: in Panama I had to wait days to see proof in certain species that males were actually stimulated to energetic display by interested or potentially interested females, and that the females without question paid attention and were influenced to receptivity by the display activities, marked by waving, of the males.

In other sections of the animal kingdom, notably among birds, a number of cases are known where the courtship display or behavior is scarcely different from, or is identical with, warning and threat. Among the best known are the displays of pheasants, grouse, and certain sandpipers and other wading birds. The same is true of many songs: the male sings both to attract the female and to let possible rivals know, preferably without a fight, that he is in possession of a nesting site and will challenge interlopers.

It is interesting to remember here that where, in the lyrebird and bowerbird the display has outgrown its function as a specialized part of the mating cycle and, as has been suggested, perhaps "become very largely of an almost recreational nature" (Stoner, 1940, p. 98), carried on throughout the year, the opposite seems to have happened in the case of fiddler crabs, where courtship display probably arose from year-round threat activities. In *latimanus*, at least, it seems now to be restricted to the breeding season.

The marvelous correlation between display and color found in the various species of birds of paradise is found to a lesser extent, but no less unquestionably, in fiddler crabs. Since courtship dances are well known in a number of insects and spiders, there seems to be no reason to deny the existence of such displays among crabs on the basis of their being invertebrates.

Conclusions: From the foregoing data on *Uca*, a few conclusions may be drawn concerning the functions of display which are applicable to the species studied at Panama, all of which appear to be relatively highly specialized forms. It is important to remember that these conclusions are not necessarily true of the entire genus.

1. Waving and its accompanying behavior in fiddler crabs form, in the various species, distinctive displays which are complemented and supplemented by temporary coloration patterns. These colors are shown to the best advantage only when the crab is in the midst of display.

2. No evidence at all has been found of the influence of sexual selection in the old-fashioned sense—that is, of a female's deliberately choosing a brightly colored or especially active crab for a mate in preference to one which was duller or slower. Nevertheless, display coloration is so closely linked with the characteristic display in the various species, that it seems very unlikely that coloration is only an accidental and useless result, or a mere waste product, of glandular

or other physiological activity, or that display is simply the result of excess energy. Instead, it seems certain that females do distinguish and recognize males of their own kind by both motion and color—as well, perhaps, as by scent or some other means—and that they are eventually attracted and stimulated to mate by the display of persistent males, which are usually among the most brilliant or acrobatic.

3. At the same time, display doubtless serves also as a warning to rival males to keep away from a chosen feeding and display territory surrounding the hole. This function also is performed in other seasons of the year in some, but not in all, species.

4. Associated with display in certain species is the erection of shelters of muddy sand above the hole. No function can be attributed to these yet, except that they probably serve as further advertisement of the presence of a male in breeding condition.

G. Breeding and Growth.

The observations at Panama were all made between January and March; the ovigerous females in the *Zaca* collection from the west coast of Central America were also taken at this season, but since these dates coincided with the dates of both trips, no real conclusions can be drawn. However, since sunlight and dryness are needed to bring out the display colors of males, and since these months are the height of the dry season, it seems reasonable to assume that fiddlers have at least a major breeding season at that time. Evidences of sexual rhythms were seen in the species studied, some being apparently near the close of the breeding season while others were obviously entering it. Some (e. g., *panamensis* and *umbratila*) were not displaying, except for a few abortive displays in the former species, nor were ovigerous females seen. An account of tidal rhythm in the display of *latimanus* has already been given (p. 155).

Ovigerous females appeared to move around less than non-ovigerous ones, but were frequently seen feeding in full sunlight. They were never the object of display by a male. It seems likely that ovigerous females of the *stylifera* group, at least, come ashore to copulate, but go down to the mud flats to carry their eggs (p. 172). No fiddlers were seen at night, even in full moonlight, on the two evenings when observations were made (c. f. Pearse, 1912).

The eggs, counted in eleven species, numbered between 500 and 15,000, relatively low totals compared with those of Cancroid crabs, for example. Similarly, the eggs are relatively larger, and of remarkably similar sizes, ranging between .24 and .27 mm. in diameter.

No special studies have been made on development, but from time to time in the following pages notes are included on the general growth trends and characteristics of young crabs of various species, which will be useful only in identification and as hints on intrageneric rela-

tionships. Detailed work must wait for the future.

Apparently no holes are dug until at least several crab instars have been passed, and the crab reached a length of 3 mm. or more. Before this time the crabs run freely in and out of the burrows of larger crabs of both their own and other species.

Young crabs in their physical characteristics, as is to be expected, frequently give clues to their relation to other species. For example, the young of *macrodactyla* can with difficulty be distinguished from adults of *zaca*. As is well known, the young lack the characteristic ridges inside the palm, the whole cheliped gains its size and elongate chelae only gradually, and often the orbits are more oblique than in the adult. Often, too, there is more pile on the carapace, or pile which is quite absent in the adult (as in *umbratila* and *oerstedii*). In *stenodactyla*, *latimanus* and their allies, however, with the carapaces semi-cylindrical and the orbits scarcely oblique, the orbits even of crabs less than 2 mm. long are similarly almost straight, although the carapace is relatively flat. In the young of crabs of the very narrow-fronted group containing *princeps* and allies, the front is wider than in the adult, but still so narrow that there is no danger of confusion with other groups of species. Spoon-tipped hairs on the second maxillipeds are fewer in young than in adults (see p. 161).

Precocity: Adolescent males, distinguishable by their smaller size and short-fingered chelipeds, sometimes may be observed apparently in the midst of learning to court and build shelters. These individuals have not attained full courtship coloration, and their movements during display show various stages of practice. The display usually is erratic and casual. Similarly, shelters may be started but not completed, or the crab may spend an entire morning building a structure which is small and badly made. Once I saw such a shelter toppled over by a strong gust of wind.

Special examples of precocious behavior were noticed in *beebei*, where an obviously immature male, without a shelter and in poor coloration, induced a female to follow him down his hole, after an energetic display. Once she was down there, however, he became frantically restless and popped out and in again every few minutes, displaying vigorously in the direction of other passing females. Another young male, this time a *stenodactyla*, after fruitlessly courting a female who paid no attention whatever, and who finally vanished down her hole around which she had just finished building a high wall (see p. 196), deliberately walked over to her wall and pulled it down with his ambulatories, trampling it into the ground until no sign of it was left. He then returned to normal feeding, without display, beside his own hole.

H. Individuality and Play.

A strong spirit of individuality was observed in the fiddler crabs, and I agree with Pearse (1912,

1914. 2) that some of their behavior can only be interpreted as sheer play. Several adjacent males of similar size, belonging to the same species, on the same day would show definite traits of individuality. One would be especially belligerent, seeking every excuse for a duel; another would build a shelter and display strenuously all day, scarcely stopping to feed; the third, although he had spent most of the preceding day fighting and courting, might on this morning feed continuously and enlarge his burrow, punctuating this activity with only a few half-hearted displays.

Similarly, some females of various species were much given to wandering about, peering down the holes of adult males, hurriedly retreating, paying brief and successive attention to the displays of a number of neighboring males, and altogether behaving in a manner which in higher animals would certainly be termed coy and flirtatious. I have used these ultra-anthropomorphic terms advisedly, because I have been unable to find any other words in the language which so exactly define the actions of these individual females. Others, of the same species, spent hours feeding quietly on several square inches of ground. In the end members of the latter group proved just as susceptible as the wandering individuals to the advances of displaying males.

Two large male *stylifera* furnished a good example of a social relationship of sorts which continued for at least a week. Their burrows were a yard apart, in an uncrowded portion of the beach, although other males of their own species were close by. Every day they followed an invariable routine, consisting of emergence, cleaning, feeding, accompanied by change to display coloration, and then—without a sign of preliminary waving or warning or argument of any kind—they would meet on the invisible boundary line between their burrows and fight. The duel always ended several minutes later in identical fashion, the smaller being somersaulted backward by the larger. The vanquished would then pick himself up and retreat hastily to his burrow, while the winner resumed feeding without another glance. After a half hour or so more both would begin to display, without taking any further notice of each other. I never saw two fights in one day, and there was never any female in their vicinity. Finally both moved away and I lost track of them.

The apparently sporting aspect of part of the courtship activities of *stenodactyla* is described on p. 196.

One of the most individualistic, inexplicable performances I saw was that of a moderate-sized but apparently adult male *terpsichores*. His display coloration was not well developed on the day in question, his usually white carapace being heavily streaked with dull yellow and his cheliped scarcely pink. He did not build a hood or display, but enlarged his burrow and fed energetically. Then, suddenly, he went straight over to the newly erected shelter of a neighbor fully eighteen

inches away. Without any provocation or preliminaries he undermined the shelter from the rear and pushed it down on top of its owner; the two crabs then spent 15 minutes fighting, in the course of which both darkened rapidly, losing all trace of display coloration, and the shelter owner lost the tip of his pollex. Finally, the aggressor let the owner go, then went directly to the next hood, six inches from the first, and repeated the episode exactly. In this case, too, the owner was powerless and was constantly thrust down his own hole, although he put up a good fight. At last, after another 25 minutes of uninterrupted struggle, the aggressor released this crab also, and returned, without any hesitation, to his first victim, who by now was cleaning himself up and had regained most of his display coloration. At the approach of his former antagonist, the victim tried to flee down his hole, but was seized from behind. Another duel, lasting no more than several minutes this time, followed, and ended as on the first two occasions by the aggressor's abruptly releasing his victim. This time the former returned slowly but directly to his own hole, cleaned himself, and began to feed. Neither of the two victims rebuilt their shelters on that day, although the tide was only slightly past dead low at the time.

The general conclusion to be drawn from all this variability of action is that fiddler crabs, nervously the most highly organized of all crustacea, show a truly remarkable latitude of behavior. This is especially striking when fiddlers are compared with ants and bees, which are tied down to severely patterned behavior by the hyper-development of their social organization.

I. Enemies and Defense.

Along the coast of Central America the greatest enemies of fiddler crabs are shore birds. At La Boca alone five species of herons, snowy and American egrets, curlews, sandpipers, herring gulls and great-tailed grackles hunted fiddlers daily at low tide. At Port Parker, Costa Rica, numerous sandpipers were hunting them. Everywhere, too, raccoon tracks were found among the fiddler holes, especially on mornings when the low tide came very early. Fiddlers were also taken from the stomach of a lizard, *Ctenosaura similis*, at Culebra, C. R., and from that of another, *Basileiscus galeritus*, on Gorgona Island, Colombia.

The crabs are adept at escaping all these enemies, and yet in wasting as little time under cover as possible. Each colony, whether mixed or formed of a single species, has worked out a scale of alarms based on the movement of suspicious objects. At La Boca noises, ranging from the cries of their bird enemies to the shouts of human beings, whistles, cannon-fire and dynamite, had no meaning for them. Neither did the passing of butterflies and wind-blown leaves within an inch or two of their eyes. But a bird flying over within twenty-five feet or a plane within, say, two hundred, was the "alert" which sent all the crabs scurrying to the mouths of

their holes, where they froze, poised for instant flight within. The "take cover" signal was the approach of a bird either on foot or wing within ten to twenty feet, depending on both bird and crab, and the approach of a human being within, on the average, thirty feet.

This distinction among "no cause for alarm," "on the alert," and "take cover" must save them a great deal of time for feeding and courting during every low tide. A most interesting point is that brightly colored adult males are the first to enter their burrows and the last to leave.

V. PHYLOGENY.

The study of the present collection of eastern Pacific fiddler crabs has shown the importance of a number of physical characteristics to which little attention has previously been paid. These, combined with the occurrence of eleven species hitherto undescribed, have clarified considerably the relations of the various species to one another. In spite of the fact that no complete picture can be formed until the genus as a whole has been similarly and more exhaustively studied, it seems worthwhile to present some tentative conclusions in regard to these relationships. (Text-figure 5).

The first necessity was to discover the primitive forms of the various physical characters, in order to decide which species were as a whole the least specialized. It appears that in a theoretical, primitive *Uca* the carapace is moderately arched, strongly narrowed behind, the orbits strongly oblique, the front moderately narrow, the major cheliped relatively small with short fingers and lacking tuberculated ridges across the palm, the minor cheliped with well developed teeth and a slight gape, the third maxilliped with a rudimentary median groove traceable only anteriorly, the second maxilliped with a moderate number of spoon-tipped hairs, and the abdominal appendage stout with a thick arm near its tip. It would presumably live in a fairly stable environment, not subject periodically to great dryness, and would have neither coloration nor display highly developed. A few species, especially *pygmaea*, *argillicola* and *helleri*, fulfill the majority of these conditions, although each of these three has already started to specialize in various divergent fashions. Unfortunately, the display of none of these has been observed.

From this theoretically primitive form, specialization has proceeded in a number of directions. These may be divided into ecological and structural, the latter being closely dependent on the former. For this reason, the former will be listed first.

1. Ecological Specialization.

a. Moving from stable, damp habitat, such as briefly exposed mud-flats, or mangrove marshes, to a periodically dry habitat, such as sloping shores or the banks of small fresh water streams.

b. Color change associated with courting.

c. Shelter-building associated with courting.

d. Display dances associated with courting.

From available material, it appears that b, c and d are most highly developed in those crabs which have been most modified for a truly littoral life.

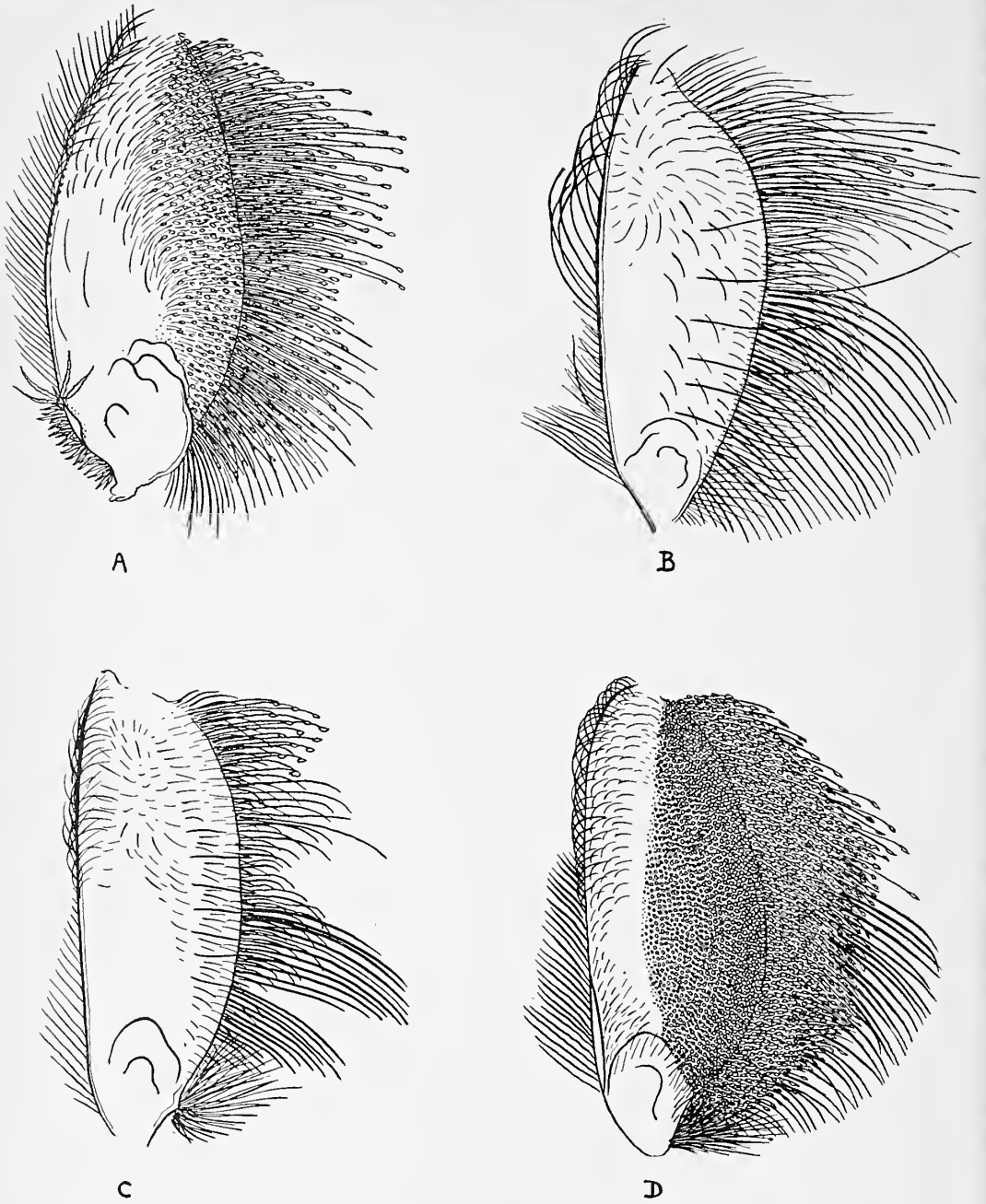
2. Structural Specializations.

a. *Increase in Thickness, through Great Arching of Carapace and Underparts, Straightening of the Orbits, Divergence of Carapace Sides Posteriorly, Fusion of Abdominal Segments:* These modifications serve the two-fold purpose of guarding against dessication, and of giving more room in the branchial chambers for the exposure of blood-vessels, an arrangement which functions as a primitive lung when the crab remains out of water for so long that the gills become temporarily useless. This increase in thickness, accomplished by most or all of the means listed above, becomes evident in end-species of Groups 2, 4 and 5, forming a good example of convergent evolution. It is most highly developed in Group 5, in which the end-forms all live a strictly littoral existence and spend hours daily exposed to the sun and air. The bottoms of the burrows of *latimanus*, the thickest of all, may not be covered by the tide for more than a week at a time. Although the species in Group 1, characterized chiefly by very narrow fronts, are in an isolated series, they are in many particulars highly specialized. They are all fairly flat, and there is some evidence to show that they come ashore only to court, but otherwise live on briefly exposed mud-flats. *U. panamensis*, the specialized crab forming Group 6, is noticeably flattened; this is probably associated with its unfiddler-like habit of hiding under stones.

b. *Specializations of Mouthparts:* The significance of most of these adaptations cannot even be guessed at. They include:

i. Grooving or smoothing of ischium of third maxilliped (Pl. VII). In the least specialized forms, and continuing through all groups except 2, 3 and end-species in Group 5, the ischium is moderately flat with a well developed inner groove and a central groove represented only by an anterior (distal) median depression. In the end-forms of Group 2 the median groove is progressively better developed, extending posteriorly (basally) and swerving inward to fuse almost or completely with the basal end of the inner groove. There seems to be no practical significance to this trend, except to show a fundamental relationship. In Groups 5 and 6 the ischium is practically smooth except for an inner groove, being flattened in Group 6, as is the rest of the crab, and broad and swollen in Group 5, the swelling being obviously merely a continuation of the general tendency to increase bulk in order to mitigate dryness.

ii. "Spooning" of hairs on merus of second maxilliped (Text-figs. 2, 3). The most usual state is for the inner edge of the anterior half of the merus and the tip of the palp to have many or all of the hairs terminating in concave, pectinated

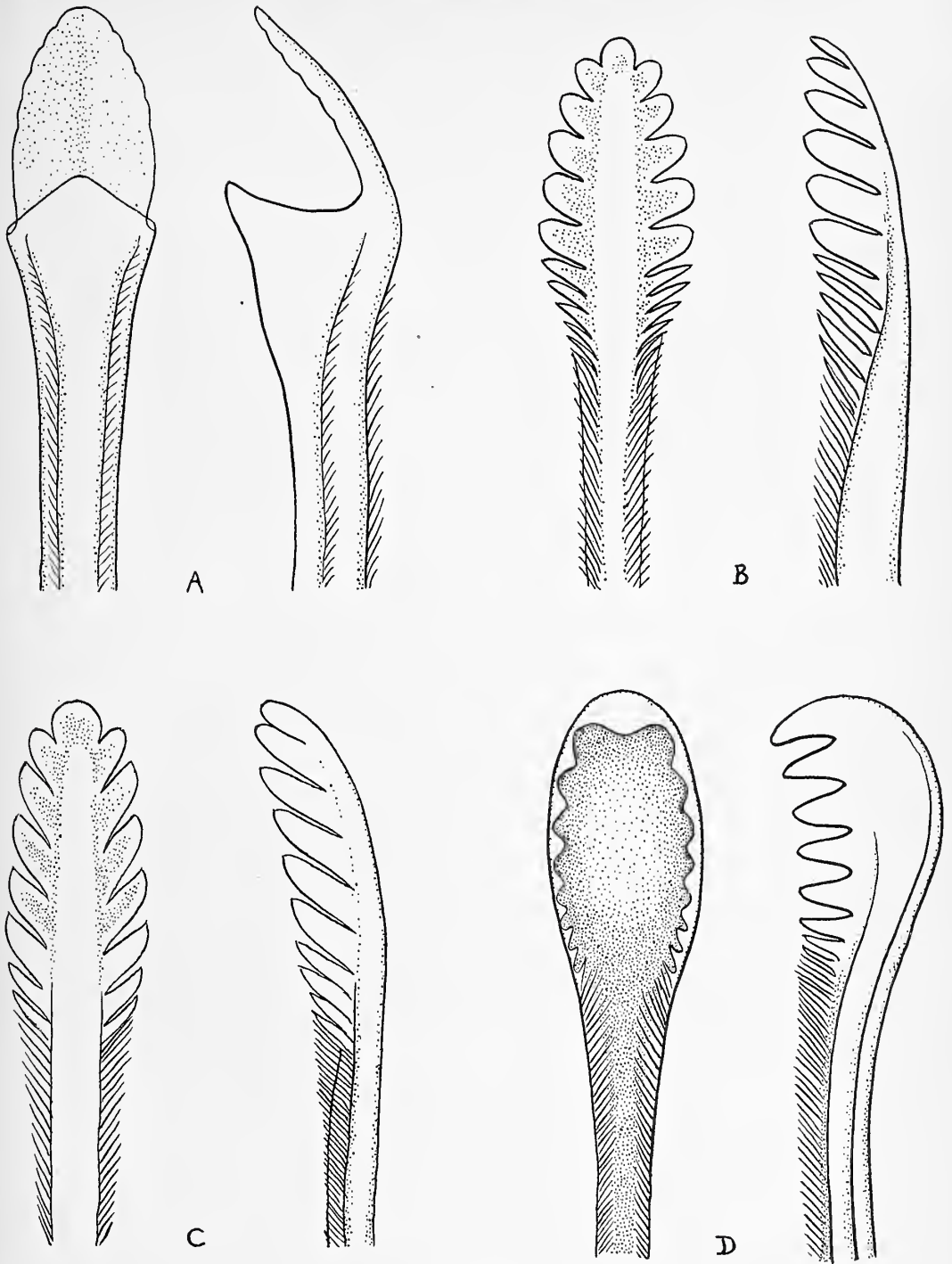


Text-figure 2.

Inner (dorsal) view of merus of second maxilliped in *Uca*. A, *princeps*; B, *mordax*; C, *oerstedii*; D, *latimanus*.

expansions, termed "spoon-shaped" for the sake of brevity. Departure from this norm extends in both directions, toward total reduction and toward tremendous increase, both of these departures taking place only in end-species. In Group 1 they are more than moderately numerous, and in addition have characteristic spines at the base of the shallow spoons, the pectina-

tions of the latter being rudimentary. Throughout Group 5, where it reaches its highest development, spooning is further increased. On the other hand, in Groups 2 and 4 the spoons become progressively fewer, until in end-forms they are almost or completely lacking. Since they are best developed in species living at least part of their lives on muddy sand shores, as opposed to semi-

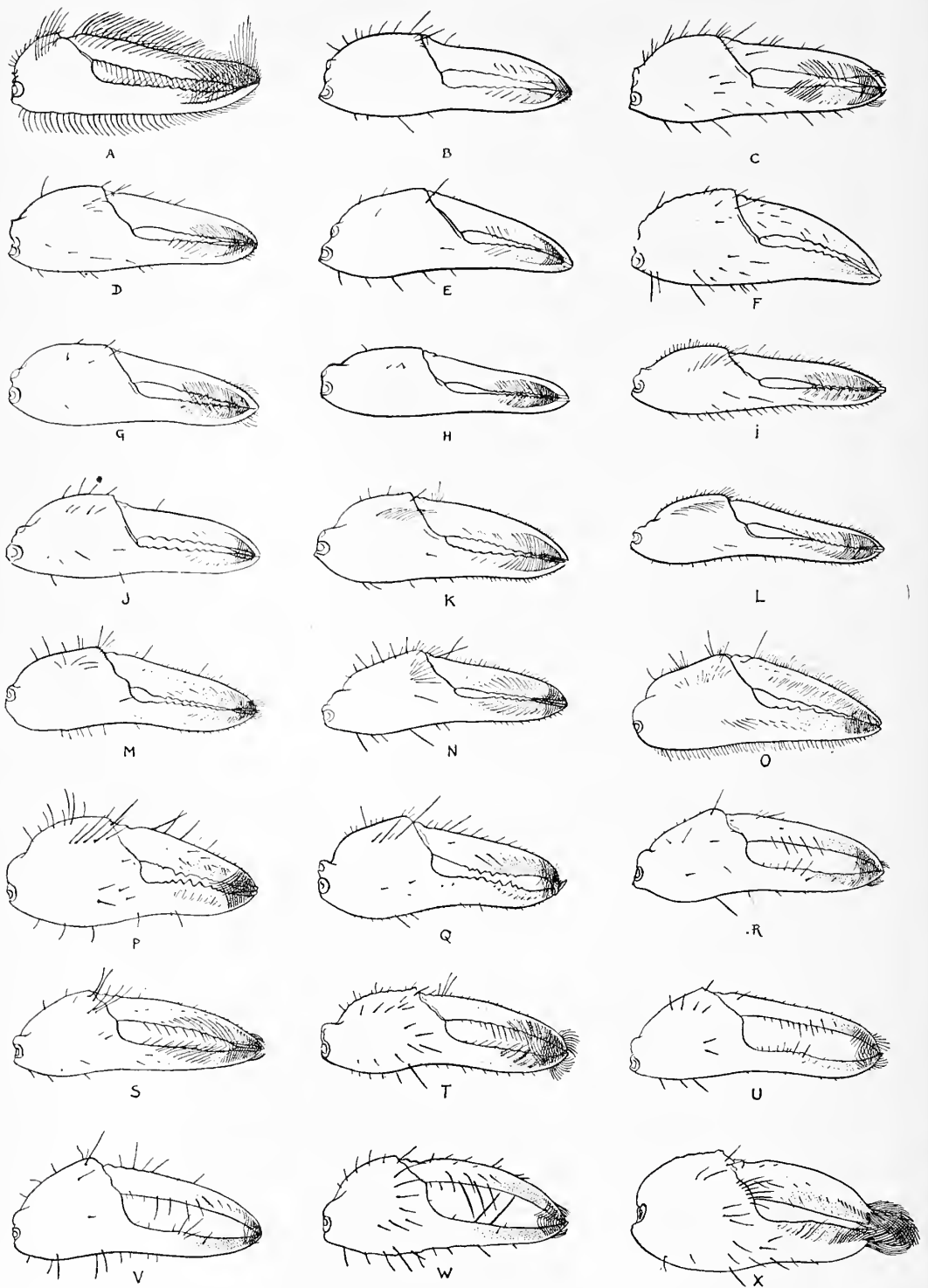


Text-figure 3.

Typical spoon-tipped hairs from merus of second maxilliped in *Uca*, front and lateral views. A, *princeps*; B, *mordax*; C, *oerstedii*; D, *latimanus*.

liquid mud, it is probable that their function is concerned with the sifting of organic detritus from this relatively dry medium.

iii. Development of "woolly" hairs on second maxillipeds. These structures have not been studied at all in detail, and they are included here



Text-figure 4.

Minor chelipeds in *Uca*. A, *heteropleura*; B, *pygmaea*; C, *zaca*; D, *galapagensis*; E, *mordax*; F, *brevifrons*; G, *macrodactyla*; H, *tomentosa*; I, *umbratila*; J, *argillicola*; K, *oerstedii*; L, *inaequalis*; M, *tenuipedis*; N, *batuenta*; O, *saltitanta* (♂); P, *bebei*; Q, *stenodactyla*; R, *helleri*; S, *crenulata*; T, *limicola*; U, *deichmanni*; V, *latimanus*; W, *terpsichores*; X, *panamensis*.

merely in order to call attention to their existence. The usual condition seems to be the occurrence of a moderate number of hairs clothed in a fuzzy material in a tuft on the inner edge of the ischium, and in a smaller tuft on the inferior (external) side of the tip of the palp. Usually there are also a few along the external edge of the merus. In Group 3 these structures are far more numerous than usual, and are somewhat increased also in Group 1. In Groups 4 and 5 they are progressively decreased, being very few in the end forms of both groups. It appears that they are most highly developed in those species living in the wettest mud, least in the truly littoral forms. The high degree of development of both spoon-tipped and woolly hairs in members of Group 1 is explained if sand-livers have more need of spoon-edged hairs in feeding, and mud-eaters of wool, since members of this species apparently spend part of their lives in both kinds of habitat. The mystery of how these specialized hairs are actually used remains, however, completely unsolved.

c. *Weakening and Loss of Minor Cheliped Teeth*: (Text-fig. 5): In Group 5, which contains the most littoral forms, the teeth progressively decrease in strength and finally vanish, this decrease being accompanied in an increase in gape and slenderness. The resultant weakness is compensated for by the strengthening of the terminal basket formed of interlocking bristles. The function of this adaptation, if any exists, is not clear. In *panamensis* (Group 6) these terminal bristles are enormously long, thick, strong and numerous, while the chelae are short and thick and toothless. These characteristics are almost certainly adaptations concerned with the crab's habit of scraping algae from the rocks.

d. *Variation of Form in the Major Cheliped*: This character is practically useless as an indication of true relationships. A number of species, very distantly related, and referable to various groups, have similar chelipeds, a general type having the fingers longer than the palm, with strong teeth, a moderate gape, and a well developed oblique tuberculated ridge on the inner side of the palm. In contrast, the two highly specialized and closely related end-forms in Group 5, *latimanus* and *terpsichores*, have utterly dissimilar chelipeds—short, broad and ridgeless, as in primitive forms, in the first species, and elongate, slender, and strongly ridged in the second. In Group 4, however, there is a general trend toward broadening and flattening of the pollex; it is possible that this is associated with the rapping of the ground in display, the increase in breadth giving perhaps more strength to withstand the rapping. However, in *batuenta*, one of the rappers, the pollex is scarcely broadened.

e. *Stridulating Ridges*: The first hints of stridulating mechanisms, consisting of a scattering of tubercles on the lower, basal, inner surface of the major palm which is opposable to a row of tubercles on the merus and carpus of the first major ambulatory, occur in *inaequalis*, a primi-

tive representative of Group 4, and in progressively greater development through some of the species of Group 5. Unfortunately, no observations have yet been made on the use of stridulation in the field; it was not seen to play a part in display on the surface of the ground.

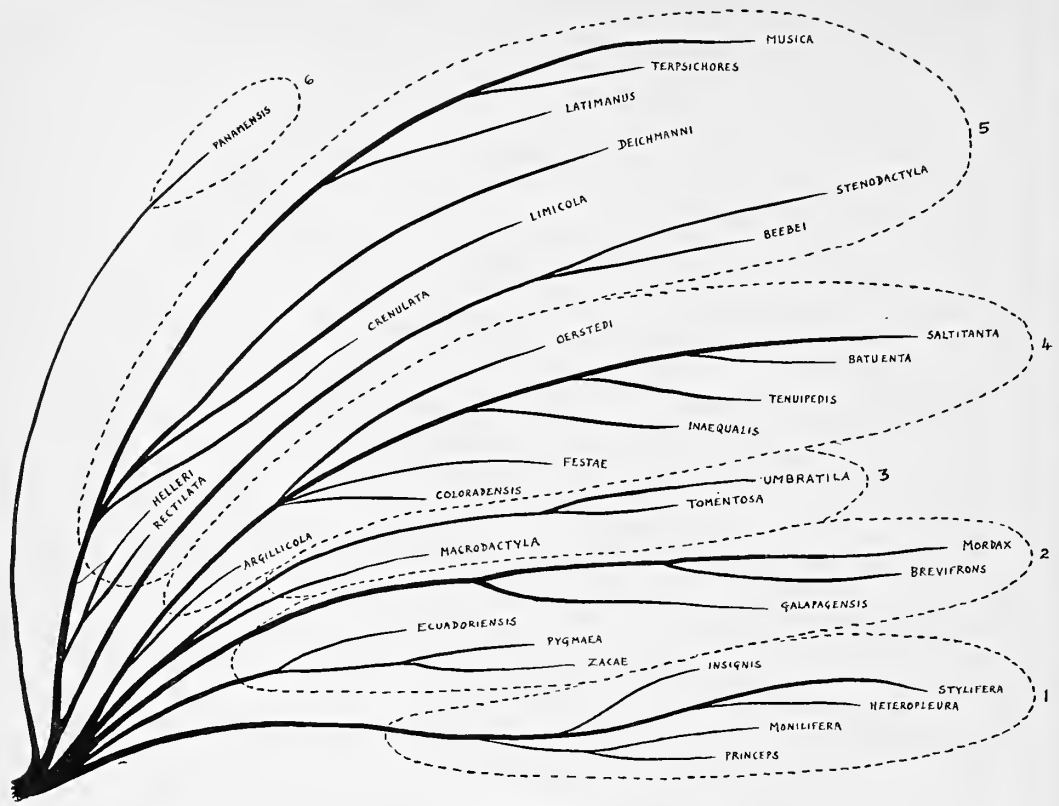
f. *Abdominal Appendage of Male*: The least specialized type seems to be short, thick, and blunt, with a short, blunt or spinous "arm" near its end. In Group 1 the end-species have slender appendages, with curved, tapering tips. In Groups 4 and 5 the appendage becomes progressively more slender and the arm reduced or absent in the end-forms of both groups. The pronounced curving of the appendage in the same species is apparently largely in conformity with the arching of the underparts in the provision for increased bulk. Some differences have been found in the form of the seminal receptacles of the females in various species. It would be interesting to work out in detail the specific adaptations of the male and female organs to each other.

g. *Color and Display*: Unfortunately color change and display have been observed only in Groups 1, 4 and 5, and until they are known in the other groups no trustworthy conclusions can be drawn concerning group relationships in this field. The prevalence of white in the display coloration of end-forms, the development of the rapping phase of display in Group 4, and the generally high level of display in all end-forms in the group have already been mentioned (p. 153ff.).

DEFINITION OF GROUPS.

The characteristics of the various groups of west coast species of *Uca*, may, using the above data, be summarized as follows:

Group 1. *princeps*, *monilifera*, *heteropleura*, *stylifera*, *insignis*. This very distinct group, which perhaps should be a subgenus, is characterized throughout by having the front exceedingly narrow, carapace little arched, cheliped massive, the chelae broad and flat; spoon-tipped hairs numerous, covering from a quarter to a half of inner surface of merus, in many rows; the individual spooned hairs are very shallow and only slightly scalloped; at their base is a sharp angle sometimes projecting as a well-developed spine. The minor chelae are large, slender, the gape slight, articulating distally, with moderately strong serrations; all margins fringed with long, thickset hairs. The shape of the abdominal appendage in the male divides the group into two: in *princeps* and *monilifera* it is thick and blunt, with the anterior arm represented by a strong spine. In the other three it is slender, tapering, the arm terminal, projecting distally. In the first two there is a tubercle beside the seminal receptacle, in the last three there is none, and the receptacle is crescentic. Observed display coloration (not seen in *insignis* or *monilifera*) reaches its highest development in *stylifera*. All live on open tidal mud flats, and some at least come to adjacent muddy sand beaches to court.



Text-figure 5.

Tentative phylogeny of eastern Pacific species of *Uca*.

Group 2. *ecuadoriensis* (position based on type description only), *pygmaea*, *zacae*, *galapagensis*, *brevifrons*, *mordax*. These seem to be relatively primitive forms, living in shady, brackish or freshwater mud, in protected places. One branch has the orbits very oblique, and chelipeds characterized by the lack of an oblique ridge and rather short fingers. The other has well formed chelipeds, with ridges and long slender fingers. Their relationship is shown by the minor chelipeds, with weak or moderate teeth, a slight gape, and progressively fewer hairs, by the grooving of the third maxillipeds and the progressively reduced spooning on the hairs of the second maxilliped, and by the broad fronts. Display unknown.

Group 3. *macrodactyla*, *tomentosa*, *umbratila*. Members of this group live in mud among mangroves. The position of *macrodactyla* may be nearer to Group 2 than 3, since its front is very wide, whereas those of *tomentosa* and *umbratila* are notably narrow. However, in the form of the minor chelae, which are strongly serrated with little gape and plentiful hairs, in the medianly smooth merus of the third maxilliped, and in the generous number of spoon-tipped hairs on the second maxilliped, the three forms are very similar. Here again the trend is from oblique to horizontal orbits. Display unknown.

Group 4. *argillicola*, *coloradensis*, *festae*, *oerstedii*, *inaequalis*, *tenuipedis*, *batuenta*, *saltitanta*. In this group the trend is from the oblique orbits and moderately arched carapace of shade-living *argillicola* to the practically straight orbits and semi-cylindrical carapace of *saltitanta*, which lives on sun-baked open mud flats. Throughout the group the spoon-tipped hairs become progressively reduced in number until in the end-forms they are practically absent, the eyebrow becomes narrower, the crenulations on the lower orbital margins obsolescent, and the arm of the abdominal appendage reduced, obsolete in end-forms. In all forms the minor chelae are strongly serrated with a very narrow gape. The major pollex in a number of species is broad and triangular, especially in *saltitanta*. The display and display coloration of *inaequalis*, *batuenta* and *saltitanta* show an interesting progression involving lightening of the color to pure white and developing of the rapping phase of display.

Group 5. This group contains the most specialized crabs and is divided into two sub-divisions composed of *beebei* and *stenodactyla* on the one hand and, on the other, of *helleri*, *rectilata* (known from type description and Holmes, 1904, illustrations), *crenulata*, *limicola*, *deichmanni*, *latimanus*, *terpsichores* and *musica*. In all the carapace is strongly arched, completely semi-cylindri-

cal in all the end-forms, and the spoon-tipped hairs on the second maxilliped are enormously developed. In the semi-cylindrical species these hairs number hundreds, their bases covering most of the inner surface of the merus as well as projecting beyond the end. Throughout the series the eyebrows increase in breadth. In *beebei* and *stenodactyla* there are a few strong teeth on the minor chelae and the arm on the abdominal appendage is lacking; in all the others, however, the chelae are progressively almost or completely without serrations and widely gaping, and there is a well developed arm on the abdominal appendage. In all the end-forms except *latimanus* the major cheliped is large with long, slim fingers. Throughout the group the trend is toward living more and more of a truly littoral life on protected flats or beaches of muddy sand. *U. latimanus* may also be found on the banks of fresh water streams, subject to seasonal drying. Coloration, display and stridulation apparently reach their highest development in this group.

Group 6. *panamensis*. This species is so isolated from the others on the west coast that it must be placed alone. It is characterized by a flattened carapace, apparently associated with its habit of living among stones, and has strong, toothless, short, minor chelae furnished with stiff brushes, which probably help in removing from the rocks the algae upon which it feeds. It has a moderate number of spoon-tipped hairs. The burrowing instinct is feebly developed. Color very variable. Display and display coloration not observed at full development.

VI. KEY TO SPECIES OF *Uca* OCCURRING ON THE WEST COAST OF AMERICA AND IN THE GALAPAGOS ISLANDS.

Including the 11 new species in the present collections, the total of apparently valid species known from the west coast of America and the Galápagos is brought to 33. Of these four—*U. galapagensis*, *U. helleri*, *U. macrodactylus* and *U. panamensis*—occur in the Galápagos, the second being indigenous.

The 22 species previously known include the 19 recognized by Miss Rathbun (1917, pp. 376 ff) and three species which have since been described, namely *U. ecuadoriensis* Maccagno, 1928, *U. inaequalis* Rathbun, 1935, and *U. deichmanni* Rathbun, 1935. *U. guayaquilensis* Rathbun, 1935, appears, from a reexamination, to be without question synonymous with *U. festae* Nobili, 1902, all being immature examples. The only recorded specimens of the latter and of *ecuadoriensis*, deposited in Turin, Italy, are unavailable for examination because of the war.

Twenty-six species are included in the present collection. All have been compared with specimens in the United States National Museum in Washington or the American Museum of Natural History, New York. Of the remaining seven known from the eastern Pacific, I have seen examples in the same institutions of all except two, *ecuadoriensis* (in Italy) and *rectilatus* (destroyed in San Francisco fire).

In making the following key an attempt was made to emphasize characteristics other than those of the major chelipeds of adult males, since these members are so often missing, gain their development so late in the life of the crab, and are useless in identifying females. With the addition of so many new, intermediate species, the use of two of Miss Rathbun's main divisions, semi-cylindrical and non-semi-cylindrical, and convex and straight antero-lateral margins, respectively, has been impracticable, except as minor subdivisions. When possible, a number of characteristics are given under each portion of the key, since crabs are so frequently damaged, and since some of the most important characters are troublesome to determine (e. g., spoon-tipped hairs and form of abdominal appendage).

In immature specimens, the form of the minor chelae, general widths of front and eyebrow and, surprisingly, the development of the arm of the abdominal appendage are the most reliable characters. Where the general group of a young specimen is in question, the number of spoon-tipped hairs on the second maxilliped is often useful, since though the full number is not developed in the young, spoon-tipped hairs are apparently never lost with growth. In the end-forms of Group 5, for example, where the spoon-tipped hairs are most highly developed, even specimens measuring 2 or 3 mm. in length have at least 25 well developed, which total at once eliminates the possibility of their belonging to the end-forms of Group 2 or Group 4.

Terms such as "width of front," "eyebrow," etc., used in the following key, are defined on page 148.

- 1a. Front narrow and spatuliform, less than 1/10 width of carapace.
 - 2a. Lateral margins either granulate or unarmed.
 - 3a. Abdominal appendage of ♂ thick and blunt; gonopore of ♀ with tubercle beside it.
 - 4a. Dorsal part of lateral margin a strong granulated line in both sexes. (Lower California—Peru). *princeps*, p. 170.
 - 4b. Dorsal part of lateral margin absent in ♂, very faint, non-granulated, in ♀. (Mexico). *monilifera* Rathbun, 1914; Rathbun, 1917, p. 380.
 - 3b. Abdominal appendage of ♂ slender and tapering; gonopore of ♀ without tubercle, crescentic.
 - 5a. Ocular stylet in ♂ absent, or no longer than cornea. ♀ with these characters: max. lgth. 10 mm.; hairs on chelae long, close-set, those on upper edge of dactyl at least as long as dactyl's breadth; triangular suborbital region nearly naked. (G. of Fonseca—Panama) *heteropleura*, p. 171.
 - 5b. Ocular stylet in ♂ always present, longer than peduncle. ♀ with these characters: max. lgth. 14.5 mm.; hairs on chelae relatively short and scant, those on upper edge of dactyl shorter than dactyl's breadth; triangular suborbital region covered with short, wide-spaced hairs. (G. of Fonseca—Ecuador) *stylifera*, p. 171.

- 2b. Lateral margins armed with large spiniform tubercles; merus joints of legs with tubercles or spines in both sexes; short ocular stylet present or absent in ♂. (G. of Fonseca to Chile).....*insignis*, p. 173.
- 1b. Front wider, increasing in width from below upward.
- 6a. Carapace little convex; front broad, about $\frac{1}{3}$ carapace width; antero-lateral angles strongly produced. Small chelae short, thick, toothless, with distal hairs thick-set, covering tips, more than a third length of chelae; gape slight. Major palm without oblique ridge, its infero-proximal angle thick, projecting backward; chelae long. (G. of Fonseca—Peru).....*panamensis*, p. 204.
- 6b. Not as above.
- 7a. Gape between small chelae slight, much less than width of middle of dactyl; serrations moderate or strong; tips dilated.
- 8a. Suborbital region almost or completely covered with short hairs.
- 9a. Orbits strongly oblique. No oblique tuberculated ridge inside major palm.
- 10a. Antero-lateral margin almost lacking.
- 11a. Palm of major cheliped much swollen; a scattering of granules on its inner surface. Spoon-tipped hairs sparse, up to about 12. (Costa Rica)
pygmaea, sp. nov., p. 174.
- 11b. Major palm not much swollen; inner surface smooth; Spoon-tipped hairs around 75. (Nicaragua, Costa Rica)
zaca, sp. nov., p. 175.
- 10b. Antero-lateral margin well developed, convex. Major chelae shorter than palm. (Ecuador) *ecuadoriensis* Maccagno, 1928, p. 49.
- 9b. Orbits scarcely oblique. Oblique ridge inside major palm present; major chelae longer than palm.
- 12a. Small chelae with plentiful hairs. Suborbital region partly naked. (Galapagos, Peru)
galapagensis, p. 176.
- 12b. Small chelae almost naked. Suborbital region densely haired. Spoon-tipped hairs from several to 20.
- 13a. Eyebrow not as wide as eyestalk, oblong. Oblique ridge inside major palm several tubercles wide, but obsolescent in large specimens; carpal eminence low. Gonopore with 2 or 3 tubercles on surrounding ridge. (Bahamas—Brazil; Western Mexico—Costa Rica)
mordax, p. 176.
- 13b. Eyebrow wider than eyestalk, triangular. Oblique ridge inside palm a single row of tubercles; carpal eminence high. Gonopore with single tubercle. (Lower Calif.—Panama)
brevifrons, p. 177.
- 8b. Suborbital region almost naked, with at most several rows of hairs close to orbital margin.
- 14a. Front narrow, $\frac{1}{6}$ to $\frac{1}{9}$ width of carapace. Gape between small chelae lacking in distal half, their teeth strong. Spoon-tipped hairs about 30–45.
- 15a. Carapace with tomentum in patches. No tooth on carpus of major cheliped. Orbits strongly oblique. Front about $\frac{1}{6}$ width of carapace. Max. lgth. 7.3 mm. (Costa Rica)
tomentosa sp. nov., p. 179.
- 15b. Carapace without tomentum, except in young. A tooth on major carpus. Orbits little oblique. Front about $\frac{1}{9}$ carapace width. Max. lgth. 19.5 mm. (Costa Rica, Panama) *umbratila* sp. nov., p. 181.
- 14b. Front wider.
- 16a. Front contained about $3\frac{1}{2}$ times in width of carapace. Carapace moderately arched. Lateral margins anteriorly well developed, convex, curving gradually backward; posteriorly strongly convergent. 30–75 spoon-tipped hairs. Oblique ridge inside major palm strong, continued to upper margin. Merus joints of legs enlarged. (Mexico—Chile; Galapagos)
macrodactyla, p. 178.
- 16b. Not with above combination of characters.
- 17a. Carapace often strongly arched, but never completely semi-cylindrical. Marginal line of front distinct. Segments of abdomen of male not fused.
- 18a. Abdominal appendage of ♂ with arm. Eyebrow almost as wide as eyestalk.
- 19a. No oblique ridge inside major palm. Orbits strongly oblique; antero-lateral margins practically absent. 50–60 spoon-tipped hairs. (Costa Rica)
argillicola sp. nov., p. 183.
- 19b. Oblique ridge present. Orbits little oblique; antero-lateral margins well-developed, straight, slanting outward. About 5–10 spoon-tipped hairs.
- 20a. Front contained about $3\frac{1}{2}$ times in carapace width. Dactyl of major cheliped about twice length of palm. Arm of abdominal appendage arising about $4\frac{1}{2}$ times its own length from tip. (Gulf of California).....*coloradensis* (Rathbun, 1933); Rathbun, 1917, p. 410.
- 20b. Front contained about $4\frac{1}{2}$ times in carapace width. Dactyl of major cheliped about three times length of palm. Arm of abdominal appendage arising about 7 times its own length from tip (Ecuador).....*festae* Nobili, 1902; Maccagno, 1928, p. 32.

- 18b. Abdominal appendage of ♂ without arm; eyebrow half or less than half width of eye-stalk.
- 21a. Antero-lateral margins not slanting outward. Pile in 8-12 small patches on carapace. A row of tubercles along carpus of first major ambulatory. Carapace not strongly convex. (Nicaragua—Ecuador)
inaequalis, p. 185.
- 21b. Antero-lateral margins slanting outward. Pile, if present, not in many small tufts. No tubercles on carpus of first major ambulatory. Carapace strongly convex.
- 22a. No oblique ridge inside major palm. Ambulatories long and slender. (Costa Rica)
tenuipedis sp. nov. p. 186.
- 22b. Oblique ridge present, meeting proximal ridge at base of dactyl above. Merus of ambulatories much enlarged. (Costa Rica, Panama)
oerstedii, p. 184.
- 17b. Carapace semi-cylindrical. Marginal line of front obsolescent or absent. Segments of abdomen of ♂ fused; no arm on abdominal appendage.
- 23a. Eyebrow less than half width of eye stalk; spoon-tipped hairs few or absent, suborbital crenulations obsolescent except externally.
- 24a. Orbital angle a right angle, not produced. No large isolated tooth externally on lower orbital margin in ♂. Minor cheliped palm slender. Base of major pollex little or no deeper than dactyl at base, merging with manus dorsally in the usual concave line. (Costa Rica, Panama)
batuenta sp. nov., p. 187.
- 24b. Orbital angle acute, produced. A large isolated tooth externally on lower orbital margin in ♂. Base of major pollex broad, merging with manus dorsally in straight line continuous with its prehensile edge. Minor cheliped palm deep, swollen, especially in ♀. (Costa Rica, Panama)
saltitanta sp. nov., p. 189.
- 23b. Eyebrow at least as wide as eyestalk. Spoon-tipped hairs more than 100. Suborbital crenulations strong.
- 25a. Ambulatories short and stout (merus of 3rd on minor side about 2/5 of its length in ♂). Tips of minor chelae not overlapping. Regions of carapace not individually tumid, sides only moderately steep. Spoon-tipped hairs projecting beyond margin about 100-140. (Nicaragua—Panama)
teebei sp. nov., p. 192.
- 25b. Ambulatories long and slender (merus of 3rd on minor side about 1/4 of its length in ♂). Tips of minor chelae overlapping. Regions of carapace strongly tumid, sides very steep. Spoon-tipped hairs projecting beyond margin about 160-250. (Gulf of Fonseca—Chile)
stenodactyla, p. 195.
- 7b. Gape between small chelae wide, at least equal to width of middle of dactyl; serrations vestigial or absent; tips of chelae usually tapering, meeting imperfectly.
- 26a. Orbits very oblique; carapace well arched but not semi-cylindrical.
- 27a. Oblique ridge inside major palm continuing only to carpal cavity. (Lower California; no specimens extant)
rectilatus (Lockington, 1877); Rathbun, 1917, p. 405.
- 27b. Oblique ridge inside palm continued to upper margin. (Galápagos only)
helleri, p. 198.
- 26b. Orbits scarcely oblique. Carapace strongly arched or completely semi-cylindrical.
- 28a. Eyebrow narrower than eyestalk. Weak serrations on minor chelae.
- 29a. Merus of ambulatories enlarged. Tip of major pollex tapering. Marginal ridge of front strong. Abdominal segments of male distinct.
- 30a. Antero-lateral margin straight. Upper margin of major palm with carina. Arm of abdominal appendage ends at least 3 times its own length from appendage tip. Carapace lgth. to 10 mm. (California and Mexico)
crenulata, p. 198.
- 30b. Antero-lateral margin concave; Upper margin of major palm without carina. Arm of abdominal appendage ends about 1½ times its own length from appendage tip. Carapace lgth. to 7 mm. (Costa Rica)
limicola sp. nov., p. 198.
- 29b. Merus of ambulatories slender. Tip of major pollex obliquely truncate. Marginal ridge of front obsolescent. 3rd-6th abdominal segments of ♂ more or less fused. (Costa Rica, Panama)
deichmanni, p. 199.
- 28b. Eyebrow at least as broad as eyestalk. No serrations on minor chelae. 3rd-6th abdominal segments of ♂ fused.
- 31a. Marginal ridge on front distinct. No oblique ridge inside major palm; major chelae shorter than palm; no stridulating ridge. (Mexico—Colombia).....*latimanus*, p. 201.

31b. Marginal ridge on front obsolete. Oblique ridge inside major palm present; chelae much longer than palm; stridulating ridge present on lower inner side of palm.

32a. Carapace moderately swollen, the branchial, buccal and pterygostomial regions not especially gibbous. Gape between minor chelae not more than 1.5 times width of minor dactyl. Arm of abdominal appendage rudimentary. Length to 6.5 mm. (Costa Rica, Panama)

terpsichores sp. nov., p. 202.

32b. Carapace greatly swollen, the branchial, buccal and pterygostomial regions separately greatly gibbous. Gape between minor chelae at least twice width of minor dactyl. Arm of abdominal appendage well developed. Length to 8 mm. (California & northern Mexico).....*musica*, Rathbun, 1914; 1917, p. 417.

VII. SPECIES OF *Uca* TAKEN BY THE EASTERN PACIFIC EXPEDITIONS OF THE NEW YORK ZOOLOGICAL SOCIETY.

Uca princeps (Smith, 1870).

Text-figs. 2, 3, 5.

(see also pp. 149, 153, 156, 165, 167).

References: *Gelasimus princeps* Smith, 1870, p. 120, pl. 2, fig. 10; pl. 3, figs. 3-3c.

Uca princeps, Rathbun, 1917, p. 382, pl. 133; pl. 160, fig. 6.

Range: San Bartolomé Bay, Lower California, to Peru.

Local Distribution: Found on open tidal mud flats and on muddy sand beaches, usually near mangrove sprouts.

Supplementary Specific Characters: Abdominal appendage of male thick and blunt, with a strong curving spine near tip. Gonopore of female located close to anterior margin of third sternal segment. This location, coupled with the presence of a large tubercle beside it, at once distinguishes the females of this species from those of *U. stylifera* and *U. heteropleura*. The strong granulated line marking dorsal part of lateral margin in both sexes distinguishes the species easily from the closely related *U. monilifera*.

Measurements: The seven specimens taken include the following extremes of length: largest male, 24.5 mm.; larger female, 19.5 mm.; ovigerous (smaller) female, 14.5 mm.; smallest male, 15 mm.

Color: Displaying males, carapace length about 15 mm., observed through binoculars: Carapace purplish gray with bluish posterior margin. Major cheliped, outer side: merus basally orange, distally dark plum, as is carpus; manus, lower two-thirds bright orange, upper third white; chelae white. Major cheliped, inner side: ischium salmon orange; merus and carpus white; manus apricot buff; chelae white. Minor cheliped purplish-gray. Ambulatories purplish-gray ex-

cept as follows: anterior (ventral) side of merus of first three legs on major side bright salmon orange, on minor side white. Buccal and pterygostomial regions white. Eyestalks yellow.

A much larger (24.5 mm.) male from Golfito, Costa Rica, observed after capture but while still alive differed from the males displaying at La Boca, Panama (described above) chiefly as follows: the upper part of the manus of the major cheliped was purple externally, the dactyl pinkish-white and the pollex scarlet, instead of white. The brown-flecked-with-white carapace of this specimen was obviously not in display coloration, since the crab had been captured.

Females and young grayish-brown, usually flecked with white.

Display: No specimens larger than about 15 mm. were seen at La Boca, but they displayed vigorously and definitely courted individual females, although none was seen actually mating. Two males were observed, to seize females after strenuous displays, and try, unsuccessfully, to drag them down their burrows. The display was as follows:

All ambulatories are held on ground, but with each gesture they are stretched upward, elevating body. Major and minor chelipeds start from position folded in front of mouth, with the carpo-manus joint elevated and the chelae hanging down. The manus and chelae of both chelipeds are then extended upward and outward, being spread slowly, then brought more quickly into position. During display, the crab, elevated high on the stretching ambulatories, runs a few steps in either direction. Each display lasts about three-quarters of a second, and an almost equal time elapses between displays.

Although a few individuals were seen at La Boca on the mud flat, only those on the muddy sand beach were displaying, although they were of similar sizes.

Breeding: As has been indicated above, males around 15 mm. long were apparently breeding at La Boca; this was in January and February; one ovigerous female was seen (not captured) at this time. On the Zaca Expedition an ovigerous female was taken in March at Golfito, Costa Rica. The eggs, which measure .24 mm. in diameter after having been preserved in alcohol, number about 15,000.

Burrow: Of displaying, moderate-sized male in stony muddy sand: slants steeply for several inches, then turns sharply and parallels ground for several more. Of male of similar size in muddy sand: slants from surface at angle of forty-five degrees, extending six to eight inches. Of large males at Golfito on gravelly mud flat: slant from surface, measuring one to two and a half feet in length, the ends lying eight inches to two feet underground.

Material: A total of seven specimens was taken at Ballenas Bay and Golfito, Costa Rica, and at La Boca, Balboa, Canal Zone. Others were seen and not collected at the latter locality. Cat. Nos. 38, 355, 38588, 4135.

Uca heteropleura (Smith, 1870).

Text-figs. 4A, 5.

(See also pp. 149, 150, 153, 154, 156, 165, 167).

References: *Gelasimus heteropleurus* Smith, 1870, p. 118, pl. 2, fig. 7; pl. 3, figs. 2-2b.*Uca heteropleura*, Rathbun, 1917, p. 385, pl. 161, figs. 1-4.*Range:* Previously known only from the Gulf of Fonseca, El Salvador. The present material extends the range four degrees southward to Panama City, Panama.*Local Distribution:* Locally abundant on tidal mud flats. Displaying males and adult females are occasionally found on muddy sand beaches, close to the edge of the mud flats.*Supplementary Specific Characters:* The present material agrees perfectly with the type description, except that the presence of the short style on the eye, on the side of the major cheliped, proves to be of relatively rare occurrence, and of variable rarity in different colonies. At Golfito, Costa Rica, there was one styled male to 12 styleless individuals; at La Boca, Canal Zone, the ratio was only about one in 25 styleless males, but a few miles away, at Bellavista, Panama City, on exactly similar terrain, there were 26 with styles to 48 without, a ratio of about three to five. The presence or absence of style has absolutely nothing to do with the size of the crab: the largest with a style measures 12 mm. long, the largest without, 16 mm.; the smallest with one is 2.9 mm. long, while the smallest without is also 2.9 mm. Likewise there is no question of damaged eyes involved. Finally, the individuals with and without styles indubitably belong to the same species: every other structural detail is identical, and likewise both coloration and display. Similarly there is no difference of habitat apparent. The explanation of the apparently adventitious occurrence of the style remains, as in *U. insignis* (p. 173), a mystery.

In a typical styled example the carapace length is 10.5 mm., the style 1.44 mm., the cornea 1.73 mm., and the stalk (including cornea but excluding style) 6.72 mm. In all styled examples the proportions are about the same.

Methods of distinguishing the female of *U. heteropleura* are given in the key (p. 167). The abdominal appendage of the male is distally slender and tapering, with a well developed arm, thicker than the extreme tip, arising near the latter.*Color:* Displaying males observed through binoculars: Carapace white. Major cheliped, externally: merus, carpus and upper half of manus purple; lower half of manus and base of pollex bright orange; tip of pollex and all of dactyl white; internally: upper inner side of merus and manus orange; otherwise much as externally. Ambulatories dark gray. Adult males on emergence at low tide are muddy brown, except the merus and manus of the major cheliped, which are yellowish-brown inside and out, and the fingers, which are white. Females plain dark brown or grayish-brown.*Display:* During display, the crab stretches up to tip-toe, lifting first and fourth ambulatories clear of ground, standing only on second and third. At the beginning, both chelipeds are folded in front of mouth with the carpo-manus joint elevated higher than the manus and chelae, which hang downwards, clearing the ground. As the crab rises to its toes, both chelipeds are extended, the manus and chelae being first stretched out sideward, then lifted by the action of merus and carpus. The chelipeds are sometimes opened all the way, sometimes only partially, depending on the degree of excitement. In maximum display, reaching up as high as possible is the ultimate object, before the chelipeds are brought down with a jerk and folded into position. Throughout display the chelae are held slightly open, parallel. Each display lasts from one-half to three-quarters of a second, with a pause between displays of about half that length of time, the speed and frequency varying with the degree of excitement. Each display takes place in one spot, but between gestures a few steps may be taken in either direction. More than one hundred displays have been observed in swift succession. The crab usually faces in one direction during the same series.

A number of ovigerous females were seen in the Canal Zone and Panama in January and February, 1941, and males were actively displaying at this time. The single ovigerous female taken carried about 3,000 eggs. In alcohol each has a diameter of .25 mm.

Measurements: The 116 specimens taken include the following extremes of length: largest male, 16 mm.; largest female, 10 mm.; ovigerous female, 6.5 mm.; smallest male, 2.9 mm.; smallest female, 4.3 mm.*Burrow:* In soft mud typical holes were remarkably shallow, slanting downward two inches from the surface, then, after a sharp bend, continuing parallel to the surface for three inches more.*Material:* A total of 116 specimens was taken at Golfito, Costa Rica, Bahia Honda and Panama City, Panama, and Balboa, Canal Zone. Innumerable other examples were seen but not collected at the two latter localities. Cat. Nos. 38,589, 38,698, 4137, 4138.*Uca styliifera* (Milne-Edwards, 1852).

Text-fig. 5.

(See also pp. 149, 150, 153-156, 159, 160, 165, 167).

References: *Gelasimus styliiferus* Milne-Edwards, 1852, p. 145 (109), pl. 3, fig. 3.*Uca styliifera*, Rathbun, 1917, p. 383, pl. 134, figs. 1 and 2.*Range:* Gulf of Fonseca, El Salvador, to Guayaquil, Ecuador.*Local Distribution:* Usual habitat seems to be tidal mud flats, although courting males were found only on muddy sand beaches.*Supplementary Specific Characters:* Abdominal appendage of male slender, tapering and strongly

curved distally. No subterminal arm. Methods of distinguishing the female are given in the key (p. 167). Unlike *U. heteropleura* and *U. insignis*, every male seen of this species had a fully developed style.

Measurements: The 24 specimens taken include the following extremes of length: largest male, 17.5 mm.; largest female, 14.5 mm.; ovigerous female, 12.5 mm.; smallest male, 6.6 mm.; smallest female, 7.4 mm. Ocular style of smallest male, 3.4 mm.; stalk and cornea together, without style, 5.1 mm.

Color: Displaying males, observed through binoculars: Carapace, including the sides, and buccal, pterygostomian and subhepatic regions pure white, except for a narrow band of dark purple on posterior edge of carapace. Major cheliped, external side: merus and carpus bright chrome yellow; manus orange, rarely rosy, with white tubercles, usually fading into white above; pollex brighter orange, dactyl pure white; internal side: pale yellow to salmon orange, except for lower half of manus and all pollex, which are pure orange. Merus and carpus of minor cheliped pale yellow; manus and base of chelae lemon yellow; tips of chelae orange. Ambulatories, except for anterior (ventral) side of certain meri, bright purple or lilac; anterior side of merus of first three on major side bright orange, the color fading into purple posteriorly; anterior side of merus of first two on minor side white, fading into purple posteriorly; rest of anterior faces of meri like posterior. Stalks and eyes greenish-yellow; styles clear lemon yellow. Sternum and abdomen apparently purple, the abdomen being marked with orange.

Adult males, not displaying, but apparently approaching the courting season, when exposed to full sunlight, have the carapace and underparts bright lemon yellow instead of white, and the colors of the major cheliped are paler than in displaying individuals. Males just emerged from their holes with the ebbing tide, captured males, and those far from the breeding season have carapace and eye-stalks pearl gray, while the other parts are dull brownish, grayish, purplish and yellowish, varying with the individual and circumstances.

Adult females in breeding condition: Carapace purplish-gray to grayish-white; ambulatories deep purple; manus and dactyls of chelipeds white; buccal, pterygostomian and subhepatic regions pale gray.

Display: Body usually not elevated at all during display, and all legs kept on ground, although body is always held fairly high. Sometimes, however, during display the crab stretches the anterior two pairs of legs, so that the anterior part of the carapace is tilted up with them, while the posterior part is lowered on the bending posterior two pairs of legs. At the beginning of display, the merus and carpus of the major cheliped are usually held almost straight out at the side, the manus and chelae being bent forward from them at right angles, the whole cheliped being held well clear of the ground. The

chelae are held parallel to each other, slightly open. From this position the crab raises the manus and chelae slowly and slightly, then lowers them to the original position equally slowly, without a pause, at the rate of one complete display to about three-quarters of a second. The display is repeated at once in continuous rhythm; when undisturbed the crab makes between thirty and fifty displays, usually about forty, at a time, hopping several steps in either direction, or to the front or back, with every gesture. Then it squats down and rests for about five seconds. The see-saw motion, brought about by stretching the front legs and lowering the back ones during display, mentioned above, may be inserted without apparent extra stimulus in the midst of a series of displays, or the entire series may be of the see-saw variety. When the crab becomes especially excited during a display, having aroused the attention of a female, it raises the second or third ambulatory simultaneously on each side, not necessarily as a pair, as it extends its cheliped; they are held motionless for an instant, then lowered, and the other two members of the same two pairs repeat the performance. The effect is that of a definite, rhythmic dance step. During display the style remains erect and motionless.

Breeding: It seems very likely that adult males and females of this species which are ready to breed come up from the mud flats on to the relative cleanliness and firmness of a muddy sand beach to court and mate. Young ones and dull colored, non-displaying males have been found only in the mud; on the muddy sand beach at La Boca, where courtship was observed, only brightly-colored males and full grown, yet non-ovigerous, females were found. On February 9, 1941, the first *U. stylifera* was observed at La Boca on the muddy sand beach, although the beach had been under observation for two weeks previously. He was in the bright yellow phase, and did not display. The next day there were five males and five females, all well separated, the males being at least six feet apart, and all in the yellow phase; the holes of the females were each at least three feet from those of the nearest males. The following day twice as many of each sex were counted in the same area, and one of the males now had the carapace pure white instead of yellow. In the days following, roughly 12 pairs were kept under observation. It appeared that during the first two to three days after their arrival on the beach the males would swing through the yellow into the pure white phase. When the latter was reached they began displaying.

In the first week of display I could not see that any of the females paid the least attention, although the burrows of individual males and females showed an increasing tendency to be dug close to each other. Later on, during the second week, many serious courtships took place daily, although I saw actual pairing, on the surface, only once (see below). Often the female would allow the male to approach her, displaying all

the way, and stroke her at the edge of her hole (p. 156), only to disappear down it at the last moment; often, if a male tried frequently to drag a female from her hole after such withdrawal, she would wait until he had temporarily given up, and then plug up her hole for the rest of the day, even though the tide was still far out. More often still, a courtship which had reached a crucial stage would be interrupted by the approach of grackles or other birds. The male always appeared to use the greatest patience and gentleness, as though afraid that sudden motions or a show of force would ruin his chances.

One male courted two females, with holes only a foot away from him and each other, indiscriminately for a week, apparently without success. When one of the females finally moved to the far side of the colony, the male continued to court the remaining one, regularly, for an hour or two a day. At the end of another week, when observations ceased, he was still adhering to the same routine; every day the procedure would reach the stroking stage several times, but I never saw them mate, or saw her approach his hole. It is interesting that his major claw was in the process of regeneration, being only about half normal size, and was pure white, like the carapace, instead of orange and yellow. His use of it in display, however, was in nowise different from that of uninjured crabs.

The single mating I observed on the surface occurred after a large, exceptionally brilliant male had courted a female, with numerous interruptions and false starts for at least three hours. The crabs assumed the position described on page 156, holding it for three minutes.

Only once did I see a male of this species induce a female to approach his hole and actually enter it. It happened after at least four days of constantly interrupted and apparently futile courtship, and after a prolonged display on the morning when she finally approached his hole. (It is possible, of course, that she had entered also on previous days, but since I had that part of the beach under almost continuous observation during the daylight low tide at that period, it is certain that she did not remain long.) As soon as she entered his hole, the male followed. A few seconds later he emerged with a load of sand, which he dumped several inches away. He continued to enlarge the hole with 33 additional loads over a period of 20 minutes. As he descended the last time he flipped in a plug after him, and, although the tide was dead low at the time, neither crab emerged the rest of the afternoon. The next day the male was feeding, and not displaying at all. He was in very poor color, the carapace being yellowish-gray where it had been dazzling white at correspondingly low tide for a week previously. The female was nowhere to be seen, and her hole, which had been about eighteen inches from that of the male for at least five days, was eradicated by the tide. The other five females in the vicinity, known to me individually, as were the above pair, by small natural recognition marks such as damaged chelae, nicks

in the carapace, etc., were all present. I dug up the hole of the male, but she was not there either. Either she had moved to an entirely different part of the beach, or—and this explanation seems likely—she had gone down to the greater moisture of the mud flat to lay and carry her eggs.

None of the females on the beach at La Boca was ovigerous. The single one in the collection was taken on a mud flat at Golfito, Costa Rica, in March. The eggs, which measured .21 mm. in diameter after having been preserved in alcohol, number about 20,000.

Burrow: The holes of large specimens usually extend about 6 to 12 inches straight down, then turn at right angles and continue for several inches more. Less frequently, they slope downward from the mouth at an angle of more than forty-five degrees, and then turn sharply, ending in the usual way a few inches beyond the bend.

At La Boca, displaying males sometimes occupied the same burrows for at least three weeks at a time; observation stopped at the end of this period. Females on the other hand tended to shift their position and dig new burrows much more frequently. The general trend seemed to be for a female to move her burrow closer to, or farther from, a male who had been courting her, although these observations are as yet incomplete. On the other hand, males too would sometimes move yards away, without any apparent reason, while individual females maintained the same holes for days at a time. The center of the opening of a burrow, although destroyed completely twice daily by the tide, rarely varied so much as a quarter of an inch in position from day to day.

Material: A total of 24 specimens was taken at Corinto, Nicaragua, at Golfito, Costa Rica, and at La Boca, Balboa, Canal Zone. Cat. Nos. 3813, 38,589, 4136.

Uca insignis (Milne-Edwards, 1852).

Text-fig. 5.

(See also pp. 149, 165, 168).

References: *Acanthoplax insignis* Milne-Edwards, 1852, p. 151, pl. 4, fig. 23.

Uca insignis, Rathbun, 1917, p. 385, pl. 161, figs. 5-15.

Range: Gulf of Fonseca, El Salvador, to Chile.

Local Distribution: Found on open tidal mud flats and at edge of mangroves, among their shoots.

Supplementary Specific Characters: Two of the males in the present collection have short styles on the eye, on the side of the major cheliped, exactly similar to those sometimes found on *U. heteropleura*. The style on the largest male (length 14 mm.) is 2.21 mm. long, and the cornea 1.92 mm. The tip of the abdominal appendage is slender.

Measurements: The four specimens taken consist of three males, 9 to 14 mm. long, and one very immature female, 8 mm. long.

Material: All are from La Boca, Balboa, Canal Zone, and from Bellavista, Panama City, Panama. Cat. Nos. 4139, 4140.

Uca pygmaea sp. nov.

Text-figs. 4B, 5; Pl. I, Fig. 1; Pl. II, Fig. 4.

(See also pp. 149, 161, 166, 168).

Diagnosis: Length under 6 mm. Carapace moderately convex; front behind eyes about 30% maximum width of carapace; orbits extremely oblique; antero-lateral margins slanting obliquely inwards immediately behind orbital angles, which are produced forward and outward into pronounced acute angles. Minor chelae serrated in middle half; gape moderate throughout to articulating tips; hairs scanty except for inner distal tuft. Major palm without oblique tuberculated ridge, which is represented only by a general scattering of granules; manus greatly swollen, but without a backwardly directed, infero-proximal projection on its outer side; dactyl about as long as palm. Merus of second maxillipeds with only about a dozen spoon-tipped hairs. Suborbital region densely hairy.

Description: A very small species. H-form depression shallow, regions not strongly delineated. Carapace smooth and naked except for a very sparse scattering of fine, short hairs. Hairs on legs few; several on each joint are long, bristle-like and dark brown at the roots.

Carapace moderately convex, widest at antero-lateral angles. Upper margin of orbit extremely oblique, sinuous. Anterior part of lateral margin so short as to be almost non-existent, slanting strongly inward from the angle, then turning almost at once at an extreme obtuse angle, as the usual elevated line. This marginal line stops opposite the anterior part of the cardiac region. Sides of carapace concave, moderately convergent posteriorly. Front between posterior margins of eyestalks about 30% width of carapace. Lower margin of front entirely, that of orbit almost, invisible in dorsal view. Eyebrow broad, showing considerable variation in the degree of inclination, even on opposite sides of the same crab. The lower orbital margin has crenulations strongly developed externally, but usually completely absent internally. Suborbital region densely hairy. Third to sixth abdominal segments of male partially fused.

Spoon-tipped hairs on merus of second maxilliped very few, about a dozen or less. Woolly hairs moderate in number, but not forming a conspicuous tuft on tip of palp. Ischium of third maxilliped with shallow central groove well developed, oblique, almost confluent basally with inner groove.

Minor chelae about as long as palm, with fairly strong serrations in middle half; distal fourth corneous, dilated, the tips articulating perfectly; gape moderate, extending to articulation. Hairs sparse, in an irregular oblique row across inner surface of each finger, well developed only distally where about half a dozen on the inner tip of each chela are long and bristle-like.

Large cheliped of male with arm and wrist weakly rugose, the wrist also tuberculous distally; distal upper edge of arm with two or three tubercles. Hand as deep as long, considerably

swollen both externally and internally. A single row of close-set tubercles along lower margin. Dorsal crest present only as a rudimentary, non-tuberculous ridge. Coarse tubercles on the outer, upper surface, continuing over on the rounded top as slightly smaller ones, and over onto the upper half of the inner surface as enlarged tubercles again. Middle outer and inner halves of manus finely granulous, lower parts practically smooth. Inner side of manus with oblique tuberculous ridge absent. A row of minute, close-set tubercles outlining dorsal margin of carpal cavity. A row of well developed tubercles extends along proximal half of upper margin of pollex and turns at a wide angle obliquely upward and backward along distal part of manus, merging with the coarse tubercles of that area. The tuberculated ridge usually present on distal edge of palm across base of dactyl is represented only by two or three small tubercles. Dactyl about as long as palm, tuberculated dorsally in proximal region, curving downward beyond end of pollex. Pollex deeper basally than dactyl, triangular, the tip obliquely truncate. Gape moderately wide, prehensile teeth rudimentary except for several enlarged teeth on each edge, typically arranged as follows: two, well separated, near base of dactyl; one on distal third of dactyl; one near base of pollex; two on truncate tip of pollex. Triangular depression on outer base of pollex very pronounced.

Merus of ambulatories scarcely enlarged.

Abdominal appendage blunt with thick, short arm paralleling it, not protruding laterally, almost reaching its tip.

Measurements: Male holotype: length 5.66 mm., breadth 8.35 mm., base of manus to tip of pollex 10.84 mm. Twelve paratypes (all males): length 4.03 to 5.47 mm. In spite of their small size, the larger ones show every indication of being adult.

Color: Captured males in life: Carapace bronzy brown, speckled or marbled with white. Large cheliped apricot buff to chestnut, except white-tipped chelae and grayish inner surfaces. Underparts entirely grayish. Upper surface of ambulatories grayish-brown, marbled with white.

Affinities: This species appears to be most closely related to *U. zaca* (p. 175). It differs in the extreme obliqueness of the orbit, in the deeper, swollen palm with coarse granulation on its inner surface, and in the paucity of spoon-shaped hairs on the merus of the second maxilliped. More distantly it is related to *U. galapagensis*, *U. mordax* and *U. brevifrons*, sharing with them as with *U. zaca* the same general type of third maxilliped, minor cheliped, male abdominal appendage, broad front and hairy suborbital region, but differing most obviously in the obliqueness of the orbits and the lack of an oblique tuberculated ridge on the inner surface of the major palm.

Local Distribution: All 13 specimens were taken from the muddy banks of a fresh water stream. The burrows were two to three inches deep.

Material: All were taken at Golfito, Costa Rica.

Cat. Nos. 381,110 (holotype) and 381,111 (paratypes).

The name *pygmaea* is proposed for this species because of its small size.

Uca zacae sp. nov.

Text-figs, 4C, 5; Pl. I, Fig. 2; Pl. II, Fig. 5.

(See also pp. 149, 159, 166, 168).

Diagnosis: Carapace moderately convex; front behind eyes slightly more than one-fourth maximum width of carapace; orbits strongly but not extremely oblique; antero-lateral margins short, straight, angled; orbital angles produced scarcely or not at all; minor chelae serrated in middle third; distal third corneous; gape moderate to articulating tips; hairs on inner surface plentiful. Oblique tuberculated ridge inside palm of major cheliped completely absent, or, rarely, represented by several rudimentary tubercles; no backwardly directed, infero-proximal projection on outer side of manus; fingers about as long as palm. Merus of second maxillipeds with many (around 75) spoon-tipped hairs. Suborbital region hairy.

Description: A small species. H-form depression moderately deep; regions otherwise scarcely delineated; surface of carapace smooth, naked except for a pair of tomentous patches in the H-form depression, between the branchial and anterior cardiac regions. There are also a few short hairs scattered irregularly over the carapace; hairs on legs yellowish or brownish, and mostly soft, not stiff and black.

Carapace moderately convex, widest at antero-lateral angles. Upper margin of orbit strongly oblique, especially in young, but not extremely so. Anterior part of lateral margins very short, usually straight, but sometimes somewhat rounded, sloping inward; the margin then turns at a very blunt, obtuse angle and is continued in a concave line to a point opposite the posterior portion of the cardiac region. Sides of carapace concave, moderately convergent posteriorly. Front between posterior margins of eyestalks slightly more than one-fourth width of carapace. Lower margin of front and lower edge of orbit visible in dorsal view. Eyebrow moderately broad and inclined. Lower margin of orbit with crenulations moderately developed externally, almost or completely lacking internally. Suborbital region hairy. Third to sixth abdominal segments in male partially fused.

Spoon-tipped hairs on merus of second maxilliped numerous, 55 to 85 or even more, arranged in about 9 to 11 rows, on distal three-fifths of inner edge. Woolly hairs moderate in number, not forming a conspicuous tuft on tip of palp. Ischium of third maxilliped with shallow central groove well developed, oblique, almost confluent with inner groove basally.

Minor chelae with fairly strong serrations in middle third; distal third corneous, little dilated, the tips articulating fairly well; gape moderate, extending to articulation. Hairs plentiful in an irregular oblique row across inner surface of each

finger, longest and strongest distally; a similar row of shorter, fewer hairs externally.

Large cheliped of male with arm rugose, and wrist weakly tuberculate. Hand at least once and a half times as long as broad with rows of tubercles—double above and single below—forming carinas on upper and lower margins; coarse tubercles distributed over upper, outer surface; rest of the latter smooth. Inner surface without oblique, tuberculous ridge, its usual position marked only by a perfectly smooth, elevated region, except in a few rare cases where several rudimentary tubercles are present. The upper margin of the carpal cavity is marked by a single row of closely set, small tubercles. A row of well developed tubercles extends from the proximal part of the upper margin of the pollex up along the distal part of the manus until, near the dorsal margin, it splays out in a small cluster of tubercles. A short row of several very low tubercles, distal to this, parallels the base of the dactyl. Except for the tubercles and ridges described, the inner side of the manus is perfectly smooth. Dactyl as long as, or slightly longer than, palm, tuberculated dorsally in proximal region, curving downward beyond tip of pollex. Latter more slender than dactyl, obliquely truncate. Gape moderately wide; a number of coarse teeth on each finger; three basal teeth of dactyl usually somewhat larger than adjacent ones; another tooth, two-thirds of way to tip, considerably enlarged; a similar one sometimes present on pollex, halfway to tip.

Merus of ambulatories scarcely enlarged, more so in females than in males; that of third leg extends about a fifth, more or less, of its length beyond antero-lateral angle when laid forward.

Abdominal appendage of male moderately blunt distally with a well developed arm extending outwards from it at an oblique angle, terminating one and one-half times its own length from the tip.

Measurements: Male holotype, length 6.9 mm., breadth 11.04 mm.; base of manus to tip of pollex, 15.1 mm.; largest female (paratype), length 6.05 mm., breadth 9.12 mm.; smallest male (paratype), length, 3.3 mm., breadth 4.8 mm.; smallest female (paratype), length 3 mm., breadth 4.2 mm.

Affinities: This species appears to be most closely allied to *U. pygmaea* (p. 174); its resemblance to the young of *U. macrodactyla* is noteworthy (see p. 178).

Range: Corinto, Nicaragua, to Golfito, Costa Rica.

Local Distribution: The 34 specimens in the collection were taken in mangrove mud (Corinto) and on the muddy banks of fresh water streams (San Juan del Sur and Golfito). Twenty-eight of the specimens were taken at Golfito from a large colony.

Material: The specimens were collected at the following localities: Corinto and San Juan del Sur, Nicaragua; Golfito, Costa Rica. Cat. Nos. 381,112 (holotype male, Golfito); 381,113 (27

paratypes, males and females, Golfoito); 381,114 (2 males, 2 females, Corinto); 381,115 (2 males, San Juan del Sur).

This species is named in honor of Templeton Crocker's yacht *Zaca*.

Uca galapagensis Rathbun, 1902.

Text-figs. 4D, 5.

(See also pp. 149, 166, 167, 168).

References: *Uca galapagensis* Rathbun, 1902, p. 275, pl. 12, figs. 1, 2; 1917, p. 403, text-fig. 167, pl. 142. Boone, 1927, p. 273 (*part.*), not fig. 97.

Range: Galápagos Islands and Peru.

Local Distribution: Salt flats and around salt ponds.

Supplementary Specific Characters: Merus of second maxillipeds with 25 or less hairs having well developed spooned tips, but many more on which minute, rudimentary spoons can be distinguished. Woolly hairs present in moderate numbers. Ischium of third maxilliped with shallow, central groove traceable in distal two-fifths.

Minor chelae slightly longer than palm, with weak serrations in middle third or third quarter; distal third or quarter corneous, dilated, the tips articulating perfectly; gape moderate, extending to articulation. Hairs sparse, chiefly in an irregular, oblique row on inner surface of each finger, longest distally; externally surface of fingers naked except for a few short rows of stumps of bristles near tip.

Suborbital region sparsely to moderately hairy.

Abdominal appendages of male moderately slender, abruptly pointed at tip; arm short, thick, parallel to appendage, not protruding laterally, terminating less than its own length from tip of arm.

Material and Discussion: The four specimens in the collection of the Department of Tropical Research were all taken by the Harrison William Galápagos Expedition (1923) and have already been recorded by Boone (1927, p. 273). They consist of the following catalogue numbers:

No. 2139. 2 males, lengths 4.4 and 4.9 mm. South Seymour Island.

No. 2624. 2 males, lengths 9 and 11 mm. James Island.

The other specimens referred by Miss Boone to this species prove upon reexamination to be distributed as follows:

No. 2042. 1 male, length 11 mm. Eden Island: Should be referred to *Uca macrodactyla* (see p. 178). This is the specimen figured in the upper half of fig. 97, p. 272 (Boone, 1927). The other small specimen catalogued under this number has completely disintegrated, and hence has been discarded.

No Number. 1 female, length 11.5 mm. Cocos Island. *Arcturus* Oceanographic Expedition. Should be referred to *Uca panamensis* (see p. 205). This is the specimen reproduced in the

lower half of fig. 97, p. 272 (Boone, 1927). Glassell (1934, p. 453) has already suggested that *U. panamensis* might be involved in this figure.

In her discussion of *U. galapagensis*, Miss Boone states (1927, p. 274) that *U. galapagensis* digs chiefly at night or in "the cool of early dawn when the tide is out . . . The huge chela of the male, and in the case of the females, either chela, form the shovel with which the sand is rolled into a pellet which is clasped by the three hinder anterior ambulatory legs, while the crab climbs out of its burrow by using its front anterior ambulatory leg and chela and its four posterior ambulatories. . . ." I have never seen *U. galapagensis* alive, but all of the twenty-odd other species of *Uca* which I have observed actually digging agreed with the observations of other students of the genus in being diurnal, in never using either cheliped as a shovel, and in almost always entering the hole with the minor side going first.

Miss Boone goes on to say that "One of the uses of the 'voice,' that is, the noise caused by the stridulating ridge of the giant chela, is to warn other members of the species that their particular burrow is inhabited, a warning that is usually respected." This sentence would be true of *Ocyopode gaudichaudii* and others of that genus, and probably of *U. musica* and some of its allies (see p. 165) as well, since these fiddlers have developed true stridulating ridges, in addition to the usual oblique, tuberculous ridges, with opposable rows of tubercles on the first ambulatory legs. However, in *U. galapagensis*, as in most other fiddlers, there is only the usual oblique tuberculous ridge on the large cheliped, which is in no position to be used for stridulation, but merely, along with the other ridges, bounds the area folded upon the merus.

Whatever the sources of Miss Boone's statements, they were not the field notes of Dr. William Beebe, director of the Harrison Williams and *Arcturus* Expeditions, nor those of any of his staff.

Uca mordax (Smith, 1870).

Text-figs. 2, 3, 4E, 5.

(See also pp. 149, 152, 157, 166, 168).

References: *Gelasimus mordax* Smith, 1870, p. 135, pl. 2, fig. 3; pl. 4, figs. 4 and 4a.

Uca mordax Rathbun, 1917, p. 391, text-fig. 166, pl. 134, figs. 3 and 4.

Range: Previously known from the Bahamas and Gulf of Mexico to Rio de Janeiro, and from the west coast of Mexico; questionably reported from Liberia. The present expeditions have extended the eastern Pacific range about 10 degrees of latitude, from Mexico to the Gulf of Dulce, Costa Rica.

Local Distribution: Found among mangrove roots and in the stony mud banks of both brackish and fresh water streams.

Supplementary Specific Characters: Spoon-tipped hairs on merus of second maxilliped almost or completely lacking; woolly hairs moderate in number. Ischium of third maxilliped with

central groove very broad, shallow, parallel to inner groove, with which it tends to merge basally, although it is scarcely traceable so far.

Minor chelae about as long as palm with fairly strong serrations in middle third; distal third horny, dilated, the tips articulating perfectly; gape slight, extending to articulation. Hairs sparse, absent on largest specimens except for a few stumps which are usually confined to the inner tip of each chela; in the young the distal hairs, as well as a few others along the usual inner oblique rows, are well developed, and there are in addition a few forming an external row.

Suborbital region hairy.

Abdominal appendage of male thick and blunt with a thick, short arm paralleling it, not protruding laterally, almost reaching its tip. Gonopore of female marked by two or three small tubercles arising from its elevated margin.

Measurements: The four specimens taken are all males and include the following extremes of length: largest, 14.5 mm., smallest 8.5 mm.

Color: Captured, living males from muddy banks of fresh and slightly brackish streams, Negritos Island and Golfito, Costa Rica: Carapace brownish-black with fine white spots, or marbled chocolate brown and white; major chelipeds orange brown with distal part of manus orange, or entirely coral red; chelae yellowish-brown, or coral tipped with white. Ambulatories and minor cheliped dark brown, spotted with white, or buff except for coral red at base of merus. Underparts grayish-white.

Discussion: Examination shows that four of the eight specimens referred by Boone (1929, p. 581, fig. 17) to *U. mordax* are examples of *U. macrodactyla*, including the specimen illustrated in fig. 17a. The remaining four were never deposited at the American Museum of Natural History, and their location is unknown. This group includes the two shown in fig. 17 b and c. It is almost certain, however, that the latter two should be referred to *U. panamensis*, as suggested by Glassell (1934, p. 454).

Material: A total of four specimens was taken from San Juan del Sur, Nicaragua, and from Negritos Island and Golfito, Costa Rica. Cat. Nos. 381,116, 381,117, 381,118.

Uca brevifrons (Stimpson, 1860).

Text-figs. 4F, 5; Pl. VII, Fig. 35.

(See also pp. 149, 151, 166, 168).

References: *Gelasimus brevifrons* Stimpson, 1860, p. 292.

Uca brevifrons, Rathbun, 1917, p. 393, pl. 138.

Uca brevifrons var. *delicata* Maccagno, 1928, p. 51, text-fig. 33.

Gelasimus vocator, Nobili, 1897, p. 6.

Range: Lower California to Panama.

Local Distribution: Found in the muddy and clayey banks of fresh water and brackish streams, close to the water level. It was collected at Port Parker at least three miles from the sea coast, in

hilly country, far above tidal influence. At Golfito, on a morning after heavy rains, a large female was found on a tree trunk, five feet above the ground, in open jungle, many yards from the nearest stream.

Supplementary Specific Characters: Spoon-tipped hairs on merus of second maxilliped very few, not more than about 20, usually far fewer, sometimes absent, apparently from being worn off; all are located on the upper inner half of the merus; the spoons are never large and broad. Woolly hairs abundant, often thickly fringing all margins of entire second maxilliped. Apparently of the same general type are hairs from which grow one or more clusters of tiny grape-like whitish globules. The number and distribution of both these and the usual woolly variety are exceeding variable in individuals; neither sex, size, nor the degree of elongation and slenderness of the cheliped (see below) accounts for it. Ischium of third maxilliped with shallow median groove well developed, confluent basally with inner groove.

Minor chelae slightly longer than manus, with six to nine strong serrations or low teeth beginning almost at their bases and extending throughout their length as far as distal fourth, which is corneous, dilated, the tips articulating perfectly. Gape slight, extending to articulation. Hairs almost absent in large specimens, only several remaining of the usual oblique row along inner surface of each finger, and the terminal bristles being represented only by stumps. External hairs practically absent. In the young, as in those of *U. mordax*, hairs are more plentiful and longer.

Suborbital region densely hairy.

Abdominal appendage of male thick, blunt, with thick, blunt arm paralleling it, not protruding laterally, and terminating almost at its tip. Gonopore of female opening near anterior margin of third sternal segment, marked by a single low tubercle.

Measurements: The 48 specimens taken include the following extremes of length: largest male, 17 mm.; largest female, 18.5 mm.; ovigerous female, 15 mm.; smallest male 3.1 mm.; smallest female, 3.5 mm.

Color: Living, captured specimens: Three large specimens taken in as many localities but in similar habitats showed great variation. The carapace of one male was dark brown, of the next cinnamon brown with fine, inconspicuous black marblings; and of the third, the tree-climbing female mentioned above, brilliant coral red. In the first the major cheliped was coral pink with tips of chelae white; in the second it was brown, like the carapace, with only the movable finger brightly colored—apricot orange; in the third, the female, both chelipeds were coral red, like the carapace, except for the lower half of the major palm and all the chelae, which were white. Upper part of ambulatories of all three like their respective carapaces; underparts of body and ambulatories like carapace or paling to white.

Breeding: The single ovigerous female was taken in January, at Port Parker. The eggs, which measure .25 mm. in diameter after having been preserved in alcohol, number about 6,000. Small specimens, measuring between 3 and 6 mm., were common on Negritos Island in March.

Young: The smallest specimens have the carapace of practically adult appearance, except for the more oblique orbits; the major cheliped, however, shows immaturity in the complete lack of a ridge on the inner side of the manus, although the triangular elevation is beginning to be apparent even in specimens of about 4 mm., and in the shortness of the fingers with narrow gape and numerous subequal teeth. The minor chelae are hairier than in the adult, and the suborbital region less hairy.

Burrow: The burrows were usually from one to two feet deep, entering the bank obliquely, or with a downward turn a few inches from the mouth; the bottoms were always under water.

Food: At Port Parker several crabs were observed feeding on mammalian faeces on the bank of a fresh water stream. Elsewhere, however, mud pellets of the usual type were found around their holes.

Discussion: *Uca brevifrons* var. *delicata* Maccagno, 1928, described from a specimen in the Turin Museum, was originally referred by Nobili (1897) to *Gelasimus vocatur*. Maccagno states that the major chelae are much more attenuated than in typical *U. brevifrons*, and the granulation of the palm less pronounced. In the light, however, of present material, this cannot be considered a valid variety. A single large cheliped in our collection was taken from Port Angeles, Mexico, in which the attenuation is midway between the "normal" and the *delicata* form. A specimen borrowed from the National Museum at San José, Costa Rica, originally collected at Golfito, is about identical with the Panamanian specimen illustrated by Maccagno, while one of the specimens catalogued under No. 19435 at the U. S. National Museum, from the Gulf of Dulce, Costa Rica, is equally or more attenuated than the Golfito specimen; in the same jar, under the same number and collected in the same locality, are examples of the typical and of intermediate forms. There is an almost equal amount of variation between individuals from the same locality in some of the specimens in the present collection. Neither Nobili nor Maccagno gives the length of the Panamanian specimen, but all those of the *delicata* type examined by me have been among the largest. The explanation of the differences is almost certainly either age or simple individual variation, or both.

A specimen from Uvita Bay, Costa Rica, 9 mm. long, is infested with *Sacculina*.

Material: A total of 48 specimens was taken from Puerto Angeles, Mexico; from San Juan del Sur, Nicaragua; and from Port Parker, Negritos Island, Uvita Bay, Golfito and Parida Island, Costa Rica. Cat. Nos. 381,119, 381,120, 381,122, 381,123, 381,124, 381,125, 381,126.

Uca macrodactyla (Milne-Edwards & Lucas, 1843).

Text-figs. 4G, 5.

(See also pp. 149, 159, 166-168).

References: *Gelasimus macrodactylus* Milne-Edwards & Lucas, 1843, p. 27; 1847, pl. 11, fig. 3. *Uca macrodactylus*, Rathbun, 1917, p. 404, pl. 143. *Uca galapagensis*, Boone, 1927, p. 271, fig. 97 (part.).

Uca mordax, Boone, 1929, p. 581, fig. 17a. (See *Discussion* on p. 177 of present paper.)

Range: Guaymas, Mexico, to Valparaiso, Chile. Galápagos (see below).

Local Distribution: Found on tidal mud flats.

Supplementary Specific Characters: Spoon-tipped hairs on merus of second maxilliped moderately numerous, usually between about 60 and 75, with most of the spoons large, broad and well developed; all are located on distal half of merus on its inner margin; they are arranged in 8 to 10 rows. Woolly hairs variable in number and arrangement, but generally abundant; the stems of many of the spoon-tipped hairs are usually woolly also. Ischium of third maxilliped with median groove rudimentary, present only distally where it forms a marginal depression.

Minor chelae slightly longer than manus, with middle half or less strongly serrated or toothed, and distal fourth corneous. Distal third dilated, the tips articulating perfectly. Gape slight, extending to articulation. Long, soft hairs present, chiefly in an oblique row along inner margin of each chela, longest and most close-set distally. A row of similar hairs close to external margin of prehensile edge of each chela. Most of the hairs on the chelae in any row are grouped into short lines of three or four each.

Suborbital region naked, except for a few hairs immediately behind crenulated anterior margin.

Abdominal appendage of male moderately slender, tapering abruptly distally to a pointed tip. Arm short, blunt, paralleling main stem, not protruding laterally, terminating about its own length from tip.

Size: The 28 specimens taken include the following extremes of length: largest male, 11 mm.; largest female, 9 mm.; smallest male, 4.5 mm.; smallest female, 4 mm. No ovigerous females were seen.

Color: Living, captured males: plain dull brown, except for the major cheliped, which is whitish.

Young: The smallest specimens taken differ from the adults most noticeably in the more oblique orbits, lack of an oblique ridge on the manus of the major cheliped, and short fingers with slight gape. On the other hand, they bear a remarkable resemblance to specimens of *U. zaca*, and care is needed to distinguish the two. Young *macrodactyla* have the orbits less oblique, the fingers shorter than the palm, and the merus of the ambulatories of both sexes dilated, while the details of the grooving of the third maxilliped and the form of the abdominal appendage are helpful checks in dubious cases.

Discussion: The major chelae vary considerably in length even in adults. Long-fingered examples have been compared with specimens in the U. S. National Museum which were included by Miss Rathbun in material for her monograph (1917). Although her illustrations were taken from a shorter-fingered example, the museum specimens include forms identical with ours. The differences, as in the similar case of *U. brevifrons*, are doubtless explained either by simple individual variation or, more probably, by the greater age of the long-fingered specimens.

A reexamination of the specimens referred by Boone (1927, p. 271 ff., fig. 97) to *U. galapagensis* shows that one male, 11 mm. in length (No. 2042), from Eden Island, Galápagos, is an example of *U. macrodactyla* and not of *U. panamensis*, as suggested by Glassell (1934, p. 453). Although this Galápagos example of *macrodactyla* differs slightly from the typical mainland form, especially in having a slightly broader front and more projecting orbital angles, the distinctions seem too slight to be used as the basis for establishing a new form, particularly since only the single specimen has been taken.

Material: In addition to the Galápagos example mentioned above, a total of 28 specimens was taken from Tenacatita Bay, Mexico (1 young male, Cat. No. 381,127) and Corinto, Nicaragua (Cat. No. 381,128).

Uca tomentosa sp. nov.

Text-figs. 4H, 5, 6.

(See also pp. 149, 166, 168).

Diagnosis: Carapace strongly convex, but not semi-cylindrical; front between eyes (measured between posterior margins of eyestalk bases) one sixth or less maximum width of carapace; antero-lateral margins short, straight, angled. Minor chelae strongly serrated in middle half, tips widely dilated, perfectly articulating; gape very slight or absent in distal two thirds. Major palm with oblique ridge well developed, continued to upper margin. No spine on carpus of major cheliped. Merus of ambulatory legs enlarged. Short, nap-like pile in reticulated pattern on carapace; black, stiff, isolated hairs on carapace and legs.

Description: A small species. H-form depression shallow, regions scarcely delineated; surface smooth, with short, thick, brownish, nap-like tomentum on branchial regions in a reticulated pattern of varying extent; sometimes it partly covers also the mesogastric, cardiac and hepatic regions. Major carpus similarly pilose, especially on upper edge and at articulation with manus. Isolated, stiff black hairs of various lengths are scattered sparsely on carapace, sternum, abdomen, eyestalks, undersides of ischia and meri of minor chelipeds and ambulatories, and on all sides of carpi and mani in both sexes; in the male several very short, black hairs occur near the articulation of the major carpus and manus.

Carapace widest at antero-lateral angles, anterior part of lateral margins very short.

straight, only about three-fifths width of front between eyes, and scarcely convergent; the margin then turns at an obtuse angle and is continued in a concave line to a point opposite middle of cardiac region. Sides of carapace concave, scarcely convergent posteriorly. Front between eyes one-sixth or less width of carapace. Lower margin of front invisible, that of orbit visible, in dorsal view. Eyebrow moderately broad, little inclined. Upper margin of orbit moderately oblique, sinuous; antero-lateral corner a right angle. Lower margin of orbit crenulated throughout. Suborbital region naked except for a single row of short hairs along crenulated margin. All abdominal segments distinct.

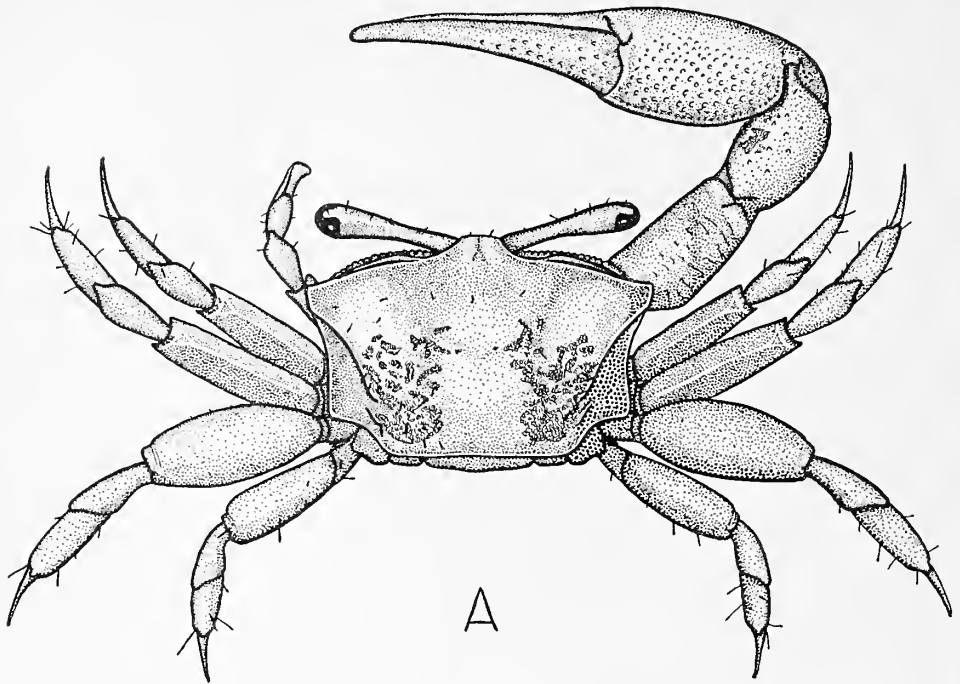
Spoon-tipped hairs of second maxilliped moderately numerous, numbering about 30 to 45, arranged in six or seven rows on anterior half of inner edge of merus. Woolly hairs plentiful, in a conspicuous group on tip of palp and along distal inner edge of merus, as well as in the more usual localities. Ischium of third maxilliped with central groove represented only by a rudimentary depression in distal margin; basally the ischium is much flattened, almost concave.

Minor chelae strongly serrated or toothed in middle half; distal fourth corneous, widely dilated, the tips articulating perfectly; gape in basal portion slight, decreasing abruptly so that distal two-thirds are almost or quite in contact; an oblique row of grouped hairs on inner surface of each chela well developed, especially distally. External surface of chelae almost or completely hairless.

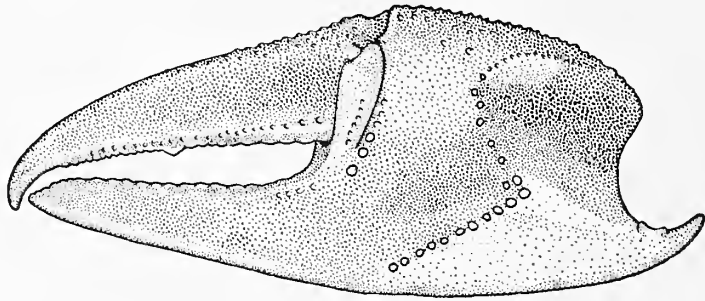
Large cheliped of male with arm and wrist faintly rugose. Hand not much longer than broad, with a low carina above; upper outer surface with coarse tubercles; rest of outside smooth. Inner surface with an oblique ridge of strong tubercles extending obliquely upward from base of pollex to carpal cavity, and continued by weaker tubercles around cavity to upper margin. Carpal eminence moderately high. A weaker, broken, tuberculated ridge extending from upper, proximal side of pollex to point on manus opposite middle of dactyl base. A third row of about six still weaker tubercles, distal to the end of the latter series, parallels the articulation of manus with dactyl. Upper, inner side of manus with a few tubercles; except for these and the tuberculated ridges, the inner surface is smooth. A row of tubercles extends along outer upper edge of pollex and its base. Dactyl slightly longer than palm, gape moderately slight, fingers not very slender, with many similar, tubercular teeth; only one is enlarged, located slightly beyond middle of prehensile edge of dactyl. Proximal half of dactyl tuberculated dorsally; a longitudinal row of tubercles on its outer surface, just above prehensile edge, extending three-fourths of distance to tip; a similar ridge on inner surface.

Merus of ambulatories much enlarged; that of third leg extends very slightly beyond antero-lateral angle when laid forward.

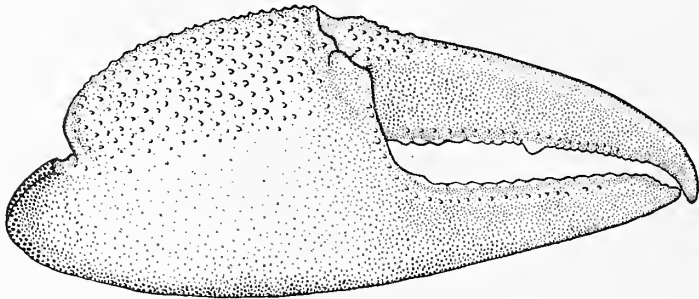
Abdominal appendage of male with tip and arm both moderately slender, the arm terminat-



A



B



C

Text-figure 6.

Uca tomentosa, holotype. Length of carapace 6.6 mm. A, dorsal view; B, major cheliped, inner view; C, same, outer view.

ing a little more than its own length from tip of appendage, and extending slightly outward from it.

Measurements: Male (holotype): length of carapace, 6.6 mm., breadth 10.2 mm.; base of manus to tip of pollex 14.5 mm.; largest female (paratype): length of carapace 7.3 mm., breadth 11.9 mm.; ovigerous female (paratype): length of carapace 6.24 mm., breadth 9.7 mm. The two remaining specimens, both non-ovigerous females (paratypes), measure 5.6 and 6.1 mm. in carapace length, respectively.

Affinities: In general characteristics this species seems to be most closely related to *U. thayeri*, although its straight, angled, antero-lateral margins, little convergence posteriorly, broader fingers with narrower gape and differently formed prehensile teeth, its black hairs and smaller size all distinguish it. The similarity of carapace pile in the two species is notable. It also has affinities to *U. umbratila* (see below).

Material: A total of five specimens, including an apparently adult male (the holotype), one ovigerous female (paratype) and three non-ovigerous females (paratypes) were taken from clay-like mud flats among mangroves at Punta-renas, Costa Rica. Cat. Nos. 381,132 (holotype) and 381,133 (paratypes).

The name *tomentosa* is given to this species because of the distinctive pile on the carapace.

Uca umbratila sp. nov.

Text-figs. 4I, 5, 7; Pl. VII, Fig. 34.

(See also pp. 149, 159, 166, 168).

Diagnosis: Carapace moderately convex; front between posterior margins of eyestalk bases about one-ninth maximum width of carapace; antero-lateral margins moderately short, straight; carapace little convergent posteriorly; merus of ambulatory legs greatly enlarged. Minor chelae strongly serrated in distal two-thirds, the serrated portions in contact when chelae are closed; tips widely dilated, articulating perfectly. Oblique ridge inside major palm well developed, continuing to upper margin, but weak in upper portion; a strong carpal spine; palm massive; fingers broad, compressed, gape slight.

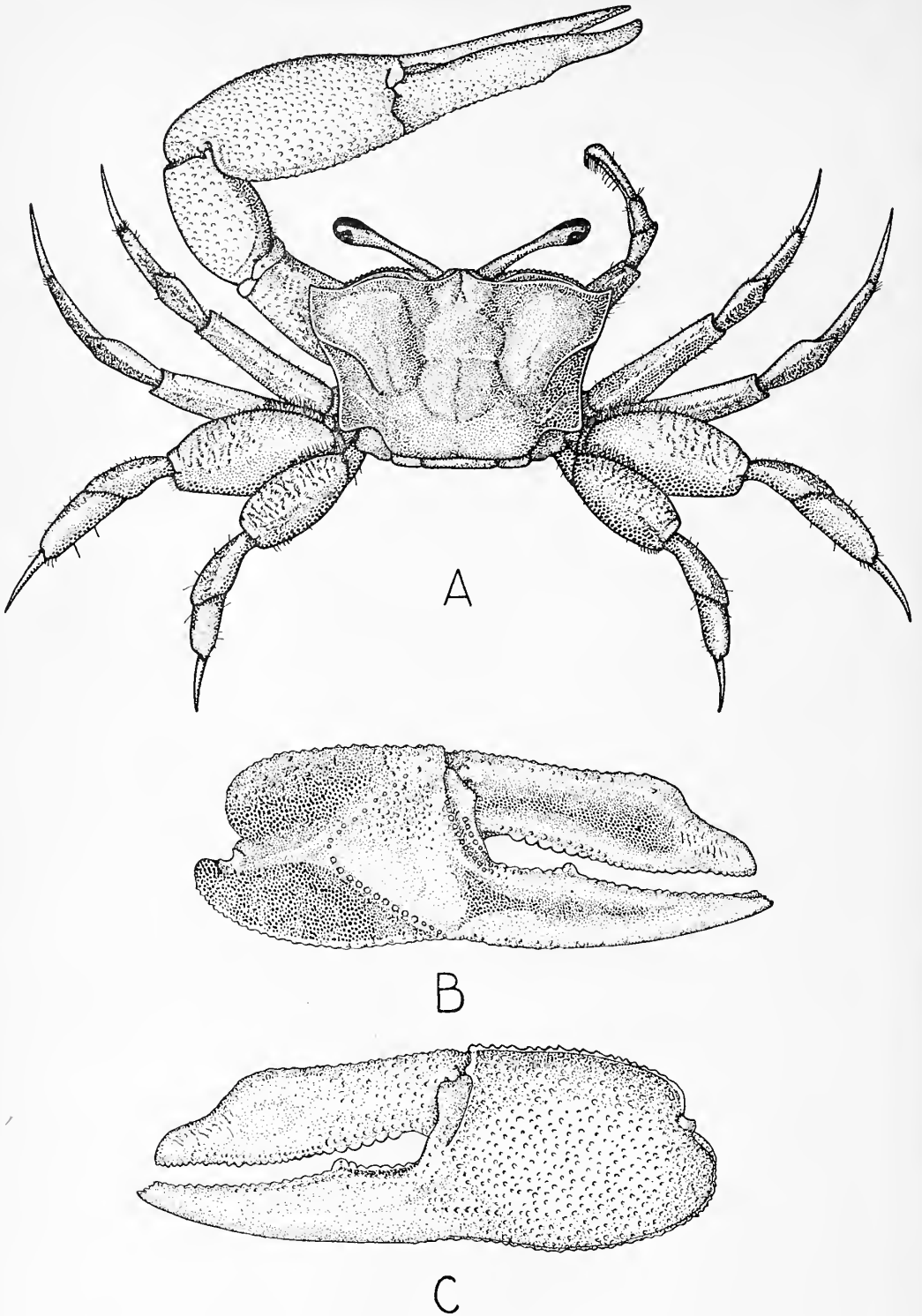
Description: A large species. H-form depression shallow, regions of carapace poorly delimited. Carapace smooth and naked. Greatest width at antero-lateral angles. Anterior part of lateral margins straight, little convergent (sometimes one side is very slightly convex), short, only about half again as long as width of front between the eyes; the margins then turn at obtuse angles and are continued in concave, rather strongly convergent lines to points opposite middle of cardiac region. Sides of carapace concave, scarcely convergent. Front between eyes contained about 9.5 times in width of carapace; a transverse, marginal ridge or line is far removed from distal edge. Lower margin of front strongly bent down, invisible in dorsal view. Eyebrows moderately broad; upper margins of orbits scarcely oblique, sinuous; antero-lateral corners acute angled, projecting forward; lower margins of orbits

crenulated throughout, visible from above. Suborbital region naked except for a single row of short hairs along crenulated margin. All abdominal segments distinct.

Spoon-tipped hairs on merus of second maxilliped moderately numerous, about 30 to 40, arranged in six to eight uneven rows on distal half of inner edge; many of the spoons are very small in this species. Woolly hairs numerous, including a conspicuous tuft on tip of palp. Ischium of third maxilliped with central groove represented only by a tiny shallow depression on anterior margin; basal portion of ischium much flattened, somewhat concave.

Minor chelae slightly longer than palm, strongly serrated in median third, this portion being in contact when chelae are closed; gape basal to this slight; corneous tips widely dilated, articulating perfectly; a row of long hairs, longest distally, on inner side in short groups; a row of short hairs along outer surface, near prehensile edges; a fringe of hairs along profiles.

Large cheliped of male with arm strongly rugose, dorsally finely tuberculate. Wrist tuberculate externally; internally, at lower edge of articulating ridge, is a strong, conspicuous tooth. Hand considerably longer than broad, quadrilateral, with a carina above and below, the upper one overhanging the carpal cavity proximally. Entire outer surface of hand coarsely tuberculate, the tubercles being larger dorsally. Inner surface of palm with an oblique, strongly tuberculated ridge from base of pollex to carpal cavity; from there it continues upward at about a right angle almost to upper margin, where it breaks up into an irregular scattering of tubercles, the most proximal of which technically continue the ridge to the upper margin. A second strong tuberculated ridge extends from upper proximal side of pollex, close to distal edge of manus up to a point on manus opposite upper part of dactyl base. A third ridge of five strong tubercles, distal to end of the latter series, lies parallel between it and articulation of manus with dactyl. Space between carpal cavity and base of dactyl weakly tuberculated, in addition to tubercles of the three ridges; inner surface of manus otherwise smooth; carpal eminence moderate. A row of tubercles extends along outer upper edge of pollex and its base. Fingers broad and flattened; gape very slight. Dactyl slightly longer than palm, its abruptly constricted tip having, in the holotype, been regenerated, or damaged while still soft. In immature males the dactyl tapers and curves slightly downward distally, in the usual fashion. Prehensile tubercles similar, larger proximally than distally, except for one, much enlarged, on pollex, one-third of distance from its base. Proximal half of dactyl tuberculated proximally and externally. A longitudinal row of small tubercles on its outer surface just above prehensile edge, extending almost to tip; a similar, but shorter, row on inner surface. Proximal halves of dactyl and pollex noticeably excavated, the deepest hollow being triangular, at junction of manus and pollex.



Text-figure 7.

Uca umbratila, holotype. Length of carapace 17.5 mm. A, dorsal view; B, major cheliped, inner view; C, same, outer view.

Merus of ambulatories much enlarged, more pilose in female than in male on upper (posterior) margins; merus of third leg extends very slightly beyond antero-lateral angle, when laid forward.

Abdominal appendage of male with tip and arm both moderately slender, tapering distally, the arm terminating a little more than its own length from the tip of the appendage, and extending slightly outward from it.

Measurements: Male (holotype): length of carapace, 17.5 mm., breadth 29 mm., base of manus to tip of pollex 48 mm.; female (paratype): length of carapace 19.5 mm., breadth 30 mm.; smallest male, length 3.65 mm.; smallest female, length 3.17 mm.

Color: Immature males and females observed through binoculars: dark gray-brown all over, except distal part of major manus, and all of dactyls, outside and in, which are all yellowish-white.

Young: The carapace and upper surface of the ambulatories of specimens up to a length of about 10 mm. are densely covered with short pile. Even in the smallest the orbits are scarcely oblique. The front is relatively wider than in adults, and, as usual, the inner surface of the major palm is smooth and the fingers short. The carpal tooth is undeveloped in the smallest. The tips of the major chelae are semi-spooned and haired, similar to the minor chelae. These young were all taken at La Boca, in January and February, when they were very abundant; not a single adult was seen at this time.

Affinities: This species is most closely related to *U. thayeri* Rathbun from the Atlantic and *U. tomentosa* (p. 179) from the Pacific. The general shape of the carapace, the narrowness of the front, and the breadth and tomentosity of the ambulatories are similar in all. *U. umbratila* has the orbits less oblique than the other two, however, lacks tomentum on the carapace in the adult, has a narrower front, and has a carpal tooth. It differs further from *U. thayeri* in the more definitely angled antero-lateral margins with projecting antero-lateral angles, in the broader, flatter fingers of the major cheliped, in their smaller gape, and in the rougher merus, carpus and manus.

Range: From Puntarenas, Costa Rica, to Balboa, Canal Zone.

Local Distribution: All were found in deeply shaded mangrove mud. The male holotype and large female paratype were taken at Puntarenas in a single hole.

Material: The 37 specimens were distributed as follows: holotype male (Cat. No. 381,129) and one paratype female (Cat. No. 381,130) from Puntarenas, Costa Rica; one adult female, in very poor condition (Cat. No. 381,131), from Ballenas Bay, Costa Rica; 34 young, males and females (Cat. No. 4118) from La Boca, Balboa, Canal Zone.

The name *umbratila* is given to this species because all of the specimens were taken in deep shade.

Uca argillicola sp. nov.

Text-figs. 4J, 5; Pl. I, Fig. 3; Pl. II, Fig. 6.

(See also pp. 149, 161, 166, 168).

Diagnosis: Carapace strongly convex, but not semicylindrical; front behind eyes about a fifth maximum width of carapace; orbits strongly oblique; antero-lateral margins extremely short, almost non-existent, continuing backward and inward as an elevated line almost immediately behind orbital angle, which is produced slightly forward and outward into an acute angle. Minor chelae strongly serrated except for horny tips, gape very slight, hairs scanty except for inner distal tuft. Oblique tuberculated ridge inside major palm absent, represented only by a scattering of granules; no backwardly directed, infero-proximal projection on outer side of manus, although the manus as a whole is somewhat swollen externally; palm deep, fingers shorter than palm. Merus of second maxilliped with about 50 to 60 spoon-tipped hairs. Suborbital region deeply depressed, almost naked.

Description: A small species. H-form depression very shallow; regions scarcely delineated; carapace smooth and naked. Hairs on legs sparse, soft and brown.

Carapace very convex, but not semi-cylindrical; widest at antero-lateral angles. Anterior part of lateral margins so short as to be almost non-existent, turning inward and backward in the form of the usual ridge practically at the antero-lateral angle; there may be slight variation in this character on two sides of the same crab. The marginal line stops opposite middle of cardiac region. Sides of carapace concave, moderately convergent posteriorly. Front between posterior margins of eyestalks about one-fifth width of carapace. Eyebrow broad, almost as broad as adjacent portion of eyestalk. The lower orbital margin has fine, low, blunt crenulations throughout its length. Suborbital region deeply depressed, naked except for one or two rows of hairs immediately behind crenulated margins. All abdominal segments distinct.

Spoon-tipped hairs on merus of second maxilliped about 50 to 60, arranged in about six or seven rows, present on slightly more than distal half of inner edge. Woolly hairs moderately few in number. Ischium of third maxilliped with central groove represented only by a marginal depression.

Minor chelae slightly longer than palm, with strong serrations or teeth throughout its length, except for a variable, very short distance proximally and the usual corneous distal fourth or fifth. Distal third dilated, the tips articulating perfectly. Gape very slight. An oblique row of sparse hairs on inner surface of each finger, thickening in length distally; a few very short hairs externally near prehensile edges.

Large cheliped of male with arm rugose, and wrist weakly rugose and tuberculated. Hand somewhat swollen externally, once and a third times as long as broad, with a low, tuberculated crest on the upper, and a row of tubercles along

the lower margin; fine tubercles, largest dorsally, are distributed over the outer surface. Inner surface without an oblique, tuberculated ridge; the latter is represented only by an irregular band of scattered granules. Upper margin of carpal cavity bounded by a single, elevated row of minute, close-set tubercles. A row of well-developed tubercles extends along the proximal half of upper margin of pollex and turns obliquely upward and back along distal part of manus, terminating in a cluster of fine tubercles a short distance from dorsal margin. Distal to this, a short row parallels base of dactyl. There is a scattering of fine granules across upper, inner surface of palm. Dactyl slightly shorter than palm, tuberculated dorsally, in proximal region, curving downward beyond tip of pollex. Both dactyl and pollex are rather deep. Tip of pollex obliquely truncate and denticulated. Gape moderate; prehensile edges with low, blunt, similar teeth, except for the enlarged, basal tooth of the dactyl, and two others opposite dorsal end of pollex.

Merus of ambulatories moderately enlarged in both sexes; that of third leg extends between a fourth and less than a fifth of its length beyond antero-lateral angle when laid forward.

Abdominal appendage of male moderately slender, tapering distally to a rounded tip; arm well developed, projecting at an angle of almost 45 degrees, terminating about one and a half times its own length from tip of appendage.

Measurements: Male holotype, length 7.8 mm., breadth 12.2 mm., base of manus to tip of pollex, 13 mm.; female paratype, length 7.3 mm., breadth 10.75 mm.; female paratype, length 5.57 mm., breadth 8.45 mm.

Color: Living specimens, observed before capture: clear, creamy white except that the entire dorsal portions of both chelipeds in both sexes are apricot buff. The color blended well with the yellowish-white clay bank in which they lived.

Affinities: This species appears to be a primitive form related on the one hand to *U. pygmaea* and its allies and on the other to the group containing *U. oerstedii* and related forms. Its strongly serrated minor chelae and narrow front distinguish it at once from members of the first group, while its oblique orbits and lack of a ridge on the major cheliped differentiate it from the second, as well as from the more distantly related *U. tomentosa* and *U. umbratila*.

Local Distribution: The three specimens in the collection were taken from yellowish-white clay banks above a slightly brackish stream. The burrows were about three inches deep. The crabs were observed to be feeding by sifting organic matter from the clay at the mouths of their burrows in typical fiddler fashion.

Material: All were taken at Golfito, Costa Rica. Cat. Nos. 381,134 (holotype) and 381,135 (paratypes).

This species is named *argillicola* in reference to its occurrence in white clay.

Uca oerstedii Rathbun, 1904.

Text-figs. 2, 3, 4K, 5.

(See also pp. 149, 153, 154, 159, 166, 169).

References: *Uca oerstedii* Rathbun, 1904, p. 161; 1917, p. 414, pl. 152, figs. 1 and 2.

Range: Previously known only from the type material, taken at Puntarenas, Costa Rica; the specimens in the present collection were taken in Panama and the Canal Zone.

Local Distribution: Common in February on open mud flats at Old Panama, near the mouth of a stream; uncommon at La Boca, Canal Zone, on open mud flats and among unshaded mangrove shoots.

Supplementary Specific Characters: A variable amount of pile is present near center of carapace, usually in two large patches, in all specimens in this collection. The larger male paratype examined at U. S. National Museum, however, had no pile.

Well developed, spoon-tipped hairs on merus of second maxilliped numbering less than 20, usually less than 15. Woolly hairs present in moderate numbers. Ischium of third maxilliped with central groove represented only by a well developed, distal, marginal depression.

Minor chelae slightly longer than palm, strongly serrated or toothed at least in middle third; distal third dilated, horny, the tips articulating perfectly. Gape in basal third slight; prehensile edges of distal two-thirds almost in contact. Oblique row of hairs along inner margins well developed, longest and strongest distally, a few very short hairs externally near prehensile edges, and along profiles.

Maximum width of eyebrow less than that of adjacent section of eyestalk. Suborbital region depressed, naked except for a row of hairs immediately behind crenulated margins.

Abdominal appendage of male moderately slender, the distal fifth curved strongly forward, scarcely tapering distally. Arm absent, represented only by a few bristles arising from a shelf slanting obliquely toward base of appendage, at point where appendage bends sharply, about four-fifths of distance to tip.

Measurements: The 21 specimens taken include the following extremes of length: largest male 7.2 mm.; largest female (ovigerous), 6.8 mm.; smallest male, 3.1 mm.; smallest female, 3.74 mm.

Color: Displaying males observed through binoculars: carapace, backs of ambulatories, buccal region, and upper and outer surfaces of all of major cheliped except dactyl dull plum purple. Dactyls of both major and minor chelipeds white inside and out. All remainder of inner surface of chelipeds, pterygostomian and subhepatic regions, and anterior (ventral) surface of ambulatories turquoise blue, the anterior sides of meri being brightest of all, approaching peacock blue.

Display: Body held fairly high, all ambulatories remaining on ground. Large cheliped, from rest position flexed in front of mouth, opens slowly outward and slightly upward, the minor

cheliped meanwhile performing a similar motion. With no pause but a slight downward jerk, they are returned in the same plane to the crooked position. There is a short rest before the display is repeated. Including the rest, each display lasts about one and a half seconds. Several steps to one side or the other are sometimes taken, the crab usually coming slowly around the hole during a series of displays or, if he stays in the same place, the anterior ambulatories are vibrated in the midst of each display, when the chelipeds are widely spread, so that the peacock blue of the quivering meri is most conspicuous.

Breeding: Males were seen displaying and females showing interest throughout February in Panama. A single ovigerous female was taken, although others were seen. The eggs, after being preserved in alcohol, measure .25 mm. in diameter and number about 4,000.

Material: A total of 21 specimens was taken at La Boca, Balboa, Canal Zone, and at Old Panama, Panama. Cat. Nos. 4119 and 4120.

Uca inaequalis Rathbun, 1935.

Text-figs. 4L, 5; Pl. II, Figs. 8, 9; Pl. III, Fig. 12.
(See also pp. 149, 153, 165, 166, 169).

Reference: *Uca inaequalis* Rathbun, 1935, p. 52.

Range: Previously known only from the holotype, taken at Guayaquil, Ecuador. The present collection was made between Corinto, Nicaragua, and the Canal Zone.

Local Distribution: Found in mud among mangroves and, more rarely, in open tidal mud flats.

Supplementary Specific Characters: The present material has been compared with the holotype at the U. S. National Museum and found to agree perfectly. In the light of these additional 50 specimens, Miss Rathbun's preliminary description may be amplified as follows:

There are usually 12 or more, rather than 8, pilous elevations on the carapace in the male. In the female these elevations are less well developed and usually almost naked. In both sexes, but especially in the male, single hairs are irregularly scattered, very sparsely, over the carapace. Carapace only moderately convex. Front behind eyes slightly less than one-third width of carapace; orbits little oblique; anterolateral margins straight, continuing backward with an angular turn; carapace moderately convergent posteriorly. Front entirely visible in dorsal view; eyebrow not nearly as wide as adjacent portion of eyestalk. Lower margin of orbit projecting, entire, except for several wide teeth, variable in size and number, on excavated, external portion. Suborbital region naked except for a few short hairs usually occurring just behind orbital border. Abdominal segments distinct.

Spoon-tipped hairs on merus of second maxilliped about 15 to 25. Woolly hairs moderately abundant. Ischium of third maxilliped with central groove represented only by a distal marginal depression.

Minor chelae almost once and a third times

length of palm, very slender, strongly serrated or toothed in third and fourth fifths; distal fifth dilated, horny, the tips articulating perfectly. Gape slight as far as serrations, practically non-existent thereafter. Both chelae covered sparsely with short hairs. Among these, the usual oblique row on inner face of each chela is not conspicuous except for the elongated distal hairs.

In the major cheliped, anterior half of carpus and posterior part of manus densely clothed externally with short pile, as is outer side of proximal two thirds of gape between chelae. Tuberculated ridge on inner surface of palm continuing only to carpal cavity, very oblique, running almost parallel to lower margin of manus; a rudimentary ridge on palm parallel to base of dactyl, then continuing down and out along upper inner edge of pollex as a well developed row of tubercles. Upper margin of palm distinctly bent over and flattened. Upper, outer portion of palm and upper, proximal part of dactyl with fine, rudimentary granulation. Inner, lower, proximal face of manus coarsely granulated. The granules, although not arranged in a linear series as in the stridulating ridges of *U. musica* and *U. terpsichores*, are nevertheless similarly complemented by a sometimes irregular row of seven to nine granules on carpus of first ambulatory on side of major cheliped; on distal end of merus of same ambulatory there are in addition usually three or four granules arranged in an angle or curve. The entire apparatus is similar to that found in *limicola* and *deichmanni*, but is better developed.

Major dactyl slightly longer than palm, curving distally over tip of flattened, triangular pollex; gape slight, with many similar, tubercular teeth, of which one on each finger, slightly beyond middle, is enlarged. Merus of ambulatories slightly enlarged in both sexes; in the male, that of the third extends about one-third its own length beyond antero-external corner of orbit when leg is laid forward, but in female only about one-fourth or one-fifth of its length.

Abdominal appendage of male slender, tapering distally, with arm completely lacking, represented only by a few hairs and an abrupt narrowing at beginning of distal seventh. The latter fraction is more strongly curved than the rest of the appendage, which, from the base, arches gradually forward.

Size: The 50 specimens taken are all smaller than the 8 mm. holotype. They include the following extremes of length: largest male, 6 mm.; largest female, 5.3 mm.; ovigerous females 4.1 to 5.3 mm.; smallest male, 2.57 mm.; smallest female, 2.9 mm.

Color: Displaying male observed through binoculars: carapace dark brown marbled with white. Major cheliped plain dark brown except as follows: upper surface of merus, carpus, manus and dactyl base rich chestnut; lower outer half of manus chestnut; distal half of dactyl and all of pollex white. Anterior (ventral) surface of meri of at least anterior two, and possibly all, pairs of ambulatories dark purple; ambulatories

otherwise dark brown marbled with white, like carapace. Buccal and pterygostomian regions brown. Sternum and abdomen apparently bluish-white.

Display: The display of only one individual was observed, on February 19, and the following observations are incomplete.

Body elevated on all four pairs of legs during each display. Large cheliped, from rest position flexed in front of mouth, opens very slowly outward and upward, making a conspicuously circular gesture. At peak it pauses infinitesimally and is then brought rapidly down, not so fast as to give the effect of a jerk. Occasionally the cheliped is brought to the ground and crooked well in front of its usual position; it is then brought back into place with a series of several thumpings of the ground, each bringing it closer to the mouth. This seems to occur when the crab is most excited. The whole display is exceedingly slow, occupying more than a second, with a pause of usually one or two seconds between displays.

Breeding: Four ovigerous females were taken in February and March, in Costa Rica and Panama. The eggs measure .24-.27 mm. in diameter, after having been preserved in alcohol, and number between 700 and 1,500.

Young: Although small examples of this species show the usual characteristics of many immature *Uca*, including a large eye, more oblique orbits, oblique antero-lateral margins scarcely distinguishable from the sides of the carapace, and small, short-fingered chelipeds with rudimentary ridges, the pilous elevations on the carapace are prominent in even the smallest males. The external surface of the major pollex has its upper and lower margins projecting, forming ridges.

Affinities: *U. inaequalis*, from the characteristics of its second maxilliped, major and minor chelipeds, orbital and suborbital regions, abdominal appendage of male and courtship display, definitely is a relatively primitive shoot on the branch giving rise to *U. oerstedii* on the one hand and to *U. batuenta* and *U. saltitanta* on the other. Its possession of a rudimentary stridulating apparatus, which is progressively better developed in the group of species terminating in *U. musica* and *U. terpsichores*, is interesting. The pilous elevations and relatively slight convexity easily distinguish it from its relatives.

Material: The 50 specimens were taken from Corinto, Nicaragua; from Puntarenas, Ballenas Bay, and Golfito, Costa Rica; and from La Boca, Balboa, Canal Zone. Cat. Nos. 381,139, 381,140, 381,141, 381,142, 4126.

Uca tenuipedis sp. nov.

Text-figs. 4M, 5. Pl. II, Fig. 7; Pl. III, Fig. 13.

(See also pp. 149, 166, 169).

Diagnosis: Carapace strongly convex, but not quite semicylindrical in lateral view; front behind eyes about one-fourth maximum width of cara-

pace; orbits little oblique; antero-lateral margins well developed, slanting outward, then continuing backward and inward with an angular turn; orbital angle usually about a right angle, sometimes slightly produced. Minor chelae strongly serrated or toothed in middle half, gape very slight, hairs plentiful on both outer and inner margins. Oblique tuberculated ridge inside major palm absent; pollex very broad basally. Merus of second maxilliped with about 15 to 25 spoon-tipped hairs. All segments of ambulatories unusually slender.

Description: A small species. Carapace with H-form depression shallow, regions poorly delimited; pile absent, but a sparse scattering of microscopic hairs over entire surface.

Carapace very convex, but not quite semicylindrical, widest behind orbital angles, at point where antero-lateral margins turn inward. These margins are straight, slanting outward, about two-thirds as long as width of front behind eyes. They then continue inward and backward with an angular turn in the form of the usual ridge as far back as posterior part of cardiac region. Sides of carapace faintly concave, little convergent. Front between posterior margins of eyestalks about one-fourth width of carapace, its margin invisible in dorsal view. Upper margin of orbit sinuous, not very oblique. Eyebrow extremely narrow, only about a quarter as wide as adjacent portion of eyestalk, strongly inclined. Lower orbital margin projecting, sparsely and irregularly crenulated in outer half; inner half entire. Suborbital region naked except for a row of hairs immediately behind crenulated margins. All abdominal segments distinct.

Spoon-tipped hairs on merus of second maxilliped numbering only about 15 to 25. Woolly hairs moderately plentiful. Ischium of third maxilliped with central grooves represented only by a marginal depression.

Minor chelae slightly longer than palm, with strong serrations or teeth throughout middle half; distal fourth slightly dilated, corneous, the tips articulating well. Gape very slight. An oblique row of hairs on inner surface of each chela, long and soft distally; another row of hairs, all moderately short, externally, and two other similar rows, along dorsal surface of dactyl and ventral surface of pollex, respectively.

Major cheliped of male with arm slightly rugose, wrist more so, both furnished with pile externally, the arm proximally, the wrist distally. Hand somewhat swollen, broad, about once and a fifth times as long as broad. Upper surface rounded, although there may be a row of fine granules; lower margin with a row of tubercles; upper and upper outer surfaces with fine sharp granules; the region is also faintly eroded; lower outer half of palm smooth.

Inner surface of large cheliped without an oblique tuberculated ridge, although there are sometimes one or two tubercles at the point where such a ridge usually meets the carpal cavity. Upper margin of carpal cavity bounded by a single row of minute, spinulous granules.

A row of well developed tubercles extends along proximal three-fourths of pollex, close to upper margin, and curves upward along distal part of manus, dying out below dorsal margin. No regular row of tubercles distal to this paralleling base of dactyl, although there may be three to five small tubercles in variable formation in this position; in the holotype four are clearly discernible, although they are very low; they are well separated and arranged in a slightly curving line. A sparse, irregular scattering of fine granules on upper half of inner surface of palm. Dactyl shorter than palm, finely tuberculated in upper proximal portion, curving downward beyond tip of pollex. Pollex roughly triangular, broader basally than dactyl, tapering abruptly along prehensile edge in distal two-fifths; tip produced slightly upward. Gape very slight; prehensile edges with low, blunt, similar teeth except for one which is slightly enlarged near base of dactyl, and another on pollex, at origin of the abrupt tapering. On external side of basal three-fifths of both dactyl and pollex, close to prehensile edge, is a row of tubercles; on pollex this row originates at lower part of dactyl's insertion, continuing around proximal end of gape, and so on out along pollex proper. A variable but small amount of pile and longer hairs is found on inner distal part of manus and proximal part of chelae, near prehensile edges.

All segments of ambulatories very slender in both sexes, the meri scarcely enlarged compared with those of other species. Merus of third ambulatory in male extending more than a quarter of its length beyond antero-lateral angle when laid forward; relatively shorter in female, though scarcely wider.

Abdominal appendage of male moderately slender, the distal half bending gradually forward, tapering slightly. Arm absent, represented only by a few bristles arising from a shelf slanting obliquely toward base of appendage, in its distal ninth.

Measurements. Male holotype; length, 5 mm.; breadth, 6.53 mm.; base of manus to tip of pollex, 8.1 mm. Larger female paratype: length, 5 mm.; breadth, 6.81 mm.; Largest male paratype; length, 5 mm. Smallest male paratype: length, 4.1 mm. Smaller female paratype: length, 4.5 mm. The largest of both sexes appear to be adult.

Affinities: This species is close to *U. inaequalis*, *U. batuenta* and their relatives. It is distinguished easily from all by the slender ambulatories and lack of an oblique tuberculated ridge inside of palm.

Local Distribution: The twelve specimens in the collection were all taken in mangrove mud at Ballenas Bay, Costa Rica.

Material: Male holotype; Cat. No. 381,143; nine male and two female paratypes, Cat. No. 381,144.

The name *tenuipedis* is given this species because of the slenderness of its legs.

Uca batuenta sp. nov.

Text-figs. 4N, 5, 8; Pl. VI, Fig. 26.

(See also pp. 149, 153, 166, 169).

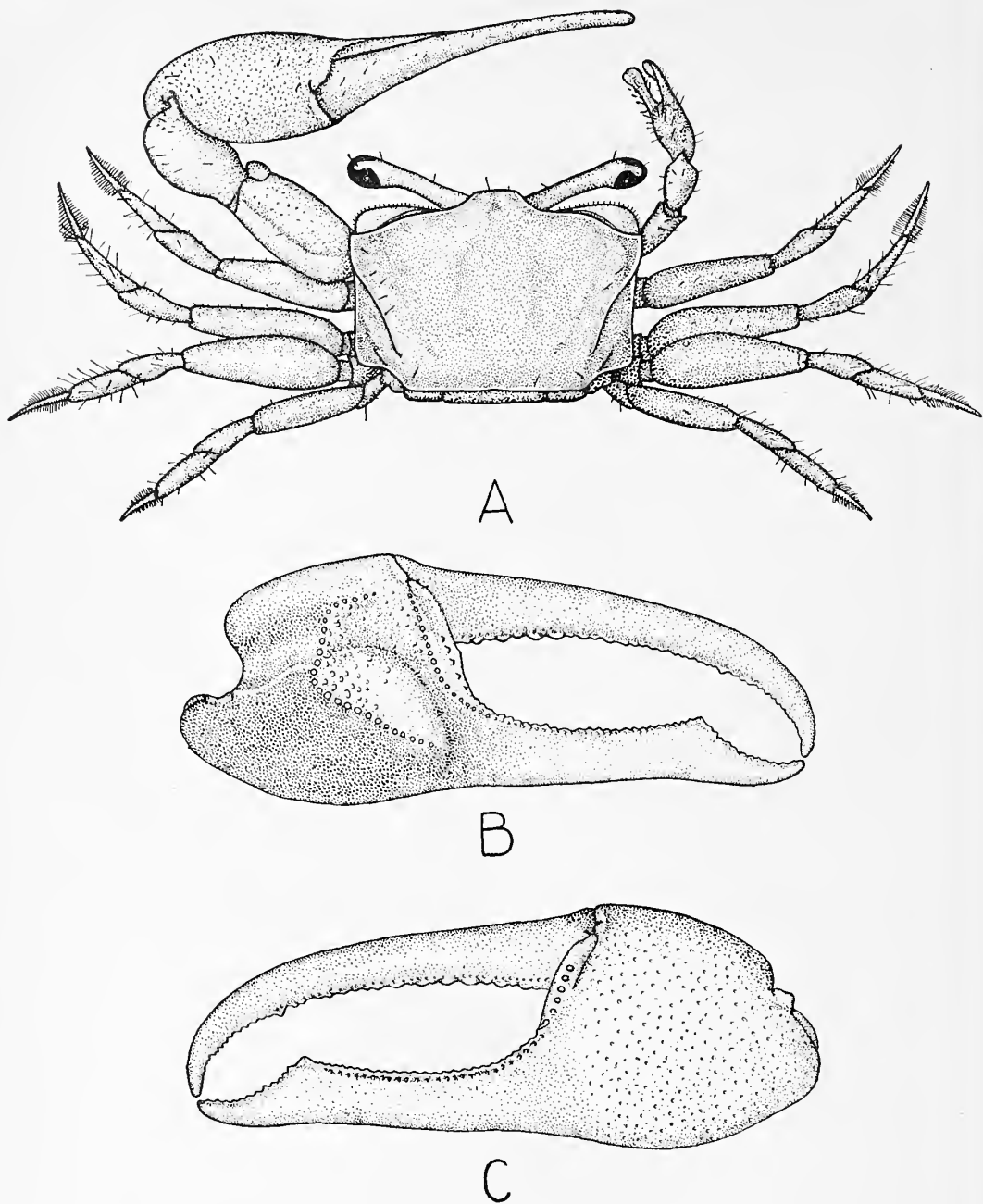
Diagnosis: Carapace strongly convex, practically semi-cylindrical in lateral view; front behind eyes a little more than one-fourth maximum width of carapace; orbits little oblique; antero-lateral margin well developed, straight or slanting a little outward, then curving backward and inward without forming a sharp angle; orbital angle a right angle, not produced. Minor chelae strongly serrated in middle half, gape very slight, hairs plentiful in rows on all margins. Oblique tuberculated ridge inside major palm present, continued to upper margin, but weak and irregular in upper portion; pollex moderately slender, not at all triangular, with an abrupt elevation on prehensile edge about three-fifths of way to tip; Merus of second maxilliped with only about a dozen or less spoon-tipped hairs. Merus of ambulatories slightly enlarged. No large, isolated teeth on outer edge of lower orbital margin. No arm on abdominal appendage of male. Eyebrow narrow.

Description: A small species. Carapace with H-form depression shallow, regions scarcely delimited, naked except for a very few widely scattered microscopic hairs.

Carapace strongly convex, practically semi-cylindrical in lateral view; widest at or behind orbital angles. Antero-lateral margins straight or slightly sinuous, usually slanting a little outward, about half as long as width of front behind eyes. They then curve gradually inward and backward, continuing in the form of the usual ridge as far as middle of cardiac region. Sides of carapace faintly concave, scarcely convergent. Front between posterior margins of eyestalks slightly more than one-fourth width of carapace, its margin invisible in dorsal view. Upper margin of orbit notably sinuous, scarcely oblique. Eyebrow very narrow, less than a third width of adjacent portion of eyestalk, strongly inclined. Lower orbital margin strongly projecting, entire, save for the occasional occurrence of several fine crenulations in extreme external corner. Suborbital region naked except for a row of hairs immediately behind orbital margin. All abdominal segments distinct.

Hairs with distinctly formed spoon-tips on merus of second maxilliped numbering a dozen or less; there may be a few more hairs with minute distal swellings. Woolly hairs relatively few in number. Ischium of third maxilliped with central groove represented only by a marginal depression.

Minor chelae slightly longer than palm, with strong teeth or serrations in middle half; distal fourth scarcely dilated, corneous, the tips articulating well. Gape slight basally, practically non-existent in serrated portions. An oblique row of hairs along inner surface of each chela, thick and long only distally; another row of hairs, all short and sparse, externally; three rows of short hairs along dorsal surface of dactyl, and two or three



Text-figure 8.

Uca batuentia, paratype. Length of carapace 4.2 mm. A, dorsal view; B, major cheliped, inner view; C, same, outer view.

along ventral side of pollex; the hair on these median rows are both short and moderately long.

Large cheliped of male with arm rugose only basally; rest of arm and wrist smooth, with a few fine hairs and, around carpo-manus joint, some short pile; long pile-like hairs inside base of arm. Hand broad, about once and a fifth or less times

as long as broad. Upper surface with a low, ill-defined crest, dying out before reaching base of dactyl. Lower margin marked by a microscopically tuberculous, elevated line. A few minute tubercles scattered over outer surface, but these are so small and low that this area appears smooth to all intents and purposes; a very few short hairs are scattered over it.

Inner surface of major palm with an oblique tuberculated ridge arising some distance proximal to base of pollex, reaching its greatest development close to carpal cavity, and dying out variably between the cavity and the dorsal margin, among an irregular scattering of tubercles. Carpal eminence well developed. A row of fine tubercles extends from proximal quarter of pollex, close to upper margin, and curves upward along distal part of manus, where the tubercles are larger, ending abruptly opposite middle of dactyl base. Distal to this, paralleling base of dactyl, a short row of fine, faint, rudimentary tubercles is sometimes distinguishable.

Major dactyl between once and a quarter and once and a half times as long as palm, smooth, moderately convex, curving downward beyond tip of pollex. Pollex slender, not triangular, with characteristic upper margin, there being an abrupt elevation or eminence about three-fifths or more of the way to the tip; basal and distal to this the margin is concave to varying degrees. Gape wide, except in the region of the eminence of the pollex. Several enlarged teeth in proximal half of dactyl, another opposite eminence of pollex. One or more surmounting and on the distal slope of this elevation are the only enlarged teeth on the pollex. In both chelae the remaining teeth are exceptionally fine and poorly developed. A row of small, close-set tubercles arising on outer side of distal end of manus continues out along proximal part of upper surface of pollex, close to prehensile margin.

Merus of ambulatories slightly enlarged in both sexes, that of third ambulatory in male extending less than a fifth of its length beyond antero-lateral margin when laid forward. A small amount of pile on carpus and manus of the three anterior ambulatories.

Abdominal appendage of male slender, curving, tapering little. Arm absent, represented only by a few bristles arising from a level shelf at beginning of distal seventh of appendage.

Measurements: Male holotype, length 4.8 mm., breadth 7.6 mm., base of manus to tip of pollex 11.8 mm.; three female paratypes (all ovigerous), length 2.9 to 4.3 mm.; nine male paratypes, length 2.7 to 4.5 mm.

Color: Displaying male observed through binoculars: carapace golden brown speckled and marbled variably with white. Merus and carpus of major cheliped, both external and internal surfaces, pinkish-brown; manus, externally and internally, bluish-white; chelae completely pure white, dazzling and polished. Buccal and pterygostomian regions golden brown speckled with white, like carapace. Anterior sides of meri of ambulatories pinkish-brown; rest of ambulatories and all of minor cheliped brown speckled and irregularly banded with white. Underparts bluish-white. Eyestalks bright green.

Display: Males were seen displaying throughout February at Balboa. The display in general is an interesting intermediate between that of *U. inaequalis* and of *U. saltitanta*, both in rapidity and in the development of the ground-rapping phase characteristic of all three. *U. batuenta*

elevates the carapace high on all four pairs of legs with each display. Cheliped is extended from folded position, in front of mouth, outward and up, the chelae meanwhile opening moderately wide. At the peak it pauses momentarily and is then brought swiftly down, but not so fast as to jerk, to a folded position well in front of the normal place, the chelae closing. Then, in most displays, the manus and chelae are literally bounced back into place with three or four raps of the ground, being drawn closer to the mouth with each rap. Minor cheliped hangs motionless during display. The crab may move along a few steps while large cheliped is elevated. The entire display, including rapping, takes about a second; a pause of one or more seconds may intervene between displays.

Breeding: The three female paratypes, all ovigerous, were taken in February, at Ballenas Bay and Puntarenas, Costa Rica. At Balboa, during the same month, females were seen to be definitely interested in the displays of the males, although mating was not observed in this species. The eggs, which measured .25-.27 mm. in diameter after being preserved in alcohol, number about 500.

Growth: The young of this species are amazingly similar to the adults of *U. tenuipedis*; young males of *U. batuenta* may be distinguished at once, however, by the presence of an oblique ridge inside the major palm, even when the chelae are still so short as to resemble those of the other species; the greater width of the ambulatories in *U. batuenta* is the other major specific character readily discernible in the young.

Affinities: This species is allied most closely to *U. tenuipedis* and to *U. saltitanta*. It is distinguished from both by the characteristic profile of the major pollex; from *U. tenuipedis* by the broader ambulatories, and from *U. saltitanta* by the non-projecting orbital angle.

Range: Puntarenas, Costa Rica, to Balboa, Canal Zone.

Local Distribution: The 13 specimens in the collection were all taken in partly shaded mangrove mud, among new shoots.

Material: Male holotype, Cat. No. 4121, La Boca, Balboa, Canal Zone; two male and one ovigerous female paratypes, Cat. No. 381,136, Puntarenas, Costa Rica; four male and two ovigerous female paratypes, also an additional, detached major cheliped, Cat. No. 381,137, Ballenas Bay, Costa Rica; three male paratypes, Cat. No. 4122, La Boca, Balboa, Canal Zone.

The name *batuenta* is given to this species in reference to its habit of beating the ground during display.

Uca saltitanta sp. nov.

Text-figs. 40, 5. Pl. II, Figs. 10, 11; Pl. III, Fig. 14; Pl. VI, Fig. 25.

(See also pp. 149, 153-156, 166, 169).

Diagnosis: Carapace strongly convex, practically semicylindrical in lateral view; front behind eyes between a fourth and a fifth maximum

width of carapace; orbits scarcely oblique; antero-lateral margin well developed, faintly sinuous, slanting outward, then turning sharply inward and backward, usually forming a distinct angle; orbital angle broadly acute, somewhat produced. Minor manus deep, especially in female; minor chelae strongly serrated throughout most of length, the serrated portions in contact; hairs plentiful in rows on all margins. Oblique tuberculated ridge inside palm of major cheliped present, extending to carpal cavity; pollex exceedingly broad, basally triangular, with prehensile edge straight or sinuous; two characteristic eminences on prehensile edge of the relatively slender dactyl. Merus of second maxillipeds without spoon-tipped hairs. Merus of ambulatories slightly enlarged. A large isolated tooth on outer edge of lower orbital margin in male. No arm on male abdominal appendage. Eyebrow narrow.

Description: A small species. Carapace with H-form depression distinct though fairly shallow. Regions scarcely delimited, although carapace is somewhat lumpy. Surface is naked except for a few microscopic hairs.

Carapace strongly convex, practically semi-cylindrical in lateral view; widest behind orbital angles. Antero-lateral margins slightly sinuous, slanting outward, about three-fourths as long as width of front behind eyes. They then turn inward and backward, usually at a sharp angle, continuing in the form of the usual concave ridge as far as level of middle of cardiac region, where they almost fuse with a similar ridge, extending from this point almost to edge of carapace above bases of last pair of ambulatories. Sides of carapace faintly concave, not converging, sometimes actually slanting outward. Front between posterior margins of eyestalks between one-fourth and one-fifth width of carapace, its margin invisible in dorsal view. Upper margin of orbit strongly sinuous, scarcely oblique. Eyebrow very narrow, less than a third width of adjacent portion of eyestalk, strongly inclined. Lower orbital margin little projecting, almost straight, with rudimentary crenulations and, at outer, excavated corner in males, two broad teeth, of which the outer is isolated; in females these are small or lacking. Suborbital region naked except for a row of hairs immediately behind orbital margin. Third to sixth abdominal segments more or less fused in male.

No hairs with distinctly formed spoon-shaped tips on merus of second maxillipeds, although there may be several with minute distal swellings. Woolly hairs relatively few in number. Ischium of third maxilliped with central groove represented only by a marginal depression.

Palm of minor cheliped deep, especially in female. Minor chelae slightly longer or shorter than palm, with strong serrations or teeth throughout all of length except a very short, variable basal area, and an unusually short, corneous area distally; the tips articulate perfectly, and are scarcely dilated. Gape slight, present only in basal half at most, usually in less. An oblique row of well developed hairs,

thickening and lengthening distally, along inner surface of each chela; another row, of short, sparse hairs along external surface; and two more rows of fairly even, close-set moderate hairs along dorsal profile of dactyl and ventral profile of pollex, respectively.

Large cheliped of male with arm extremely finely rugose and tuberculate basally, smooth distally; most of wrist externally similarly sculptured. Short pile on inner side near dorsal profile of distal part of arm, all of carpus and proximal part of manus. Hand almost or quite as broad as long. Upper surface rounded, except for the sharp boundary of carpal cavity, and exceptionally short; lower margin marked by an elevated line of microscopic, close-set granules. Entire upper and outer surface covered with moderately large, low tubercles. Up to half a dozen short, dark hairs may be scattered over it.

Inner surface of major palm with an oblique tuberculated ridge arising near base of pollex close to ventral profile and extending to carpal cavity; the ridge is irregular, varying in width, from one to two tubercles, and in the size of the latter. Between carpal cavity and dorsal profile is only a scattering of fine tubercles. Carpal eminence scarcely developed. A row of tubercles, almost straight because of the width of the pollex base, extends on palm from lower part of base obliquely down and out along upper margin of pollex, close to prehensile edge; basal five or six tubercles large and close-set, beyond that they are tiny and die out in distal half of thumb as an elevated ridge. There is no additional ridge paralleling base of dactyl on inner distal end of palm.

Major dactyl slender, about twice as long as palm, with a few fine tubercles on dorsal, proximal profile, curving downward beyond and overlapping tip of pollex; the dactyl has a characteristic prehensile profile formed by the presence of two eminences, one at about a quarter of the way, the other at half the way to tip; the profile before, between and beyond the eminences is concave. Pollex exceedingly broad basally, triangular, tip abruptly tapering, curving upward; prehensile margin straight or slightly sinuous. Gape almost non-existent; the distal edges can be brought into actual contact, the long, curving dactyl tip passing to the inside of that of the pollex. Prehensile teeth numerous, small, poorly developed except for single enlarged teeth on summit of each eminence of the dactyl and, sometimes, on pollex at about two-thirds of distance to tip. On the outer surfaces of both pollex and dactyl a row of fine, close-set tubercles extends most of the length of the chela, close to and parallel with the prehensile margin. A more or less distinct elevated line passes along outer lower side of pollex; above this is a depressed area.

Merus of ambulatories moderately enlarged in both sexes, that of third ambulatory in male extending about a quarter of its length beyond antero-lateral margins when laid forward. A small amount of pile on carpus and manus of the three anterior ambulatories.

Abdominal appendage of male slender, curving, tapering. Arm absent, represented only by a tuft of bristles arising from a shelf slanting obliquely toward base of appendage, about six-sevenths of distance to tip.

Measurements: Male holotype, length 6 mm., breadth 8.8 mm., base of manus to tip of pollex, 12.2 mm.; 5 ovigerous female paratypes, lengths 3.8 to 5.3 mm.; 2 non-ovigerous female paratypes, lengths 3 and 3.3 mm.; 7 male paratypes, lengths 3.5 to 6.1 mm.; 116 other males, 42 ovigerous females and 28 non-ovigerous females of intermediate lengths.

Color: Displaying males observed through binoculars: usually pure white, though occasionally the carapace is grayish or yellowish, or has a few sparse markings of rich brown; it is probable that these individuals simply have not reached full display coloration, although when observed they were displaying vigorously. Females and young inconspicuous dark grayish or dark brownish, probably mottled. Eggs magenta.

Display: Throughout February at Balboa, these crabs were obviously at the height of the breeding season; and, in the broad open mudflats which were their habitat, they were certainly the dominant species of *Uca*; the summit of every tiny elevation in the mud was employed by a displaying male; in some places there were an average of four displaying males to the square foot.

During each display the body is raised high on all four ambulatories, which meanwhile carry it along three or four steps in either direction, or else the crab may stand in one place. Major cheliped is lifted from position folded in front of mouth, opened and stretched diagonally straight up and out, the chelae meanwhile opening wide; it is then brought down at once without pause practically in the same place from which it started, though it may fall a little more to the front. At the same time the body is lowered and the chelae closed. Then the manus and chelae are vibrated up and down against the ground three or four times with extreme rapidity. At end of each display is an infinitesimal pause, so that the accent is there, not when the cheliped is elevated. The display is then repeated, sometimes upward of a hundred times without rest. During each display the minor cheliped is half spread outward, then returned to folded position. There may be as many as two full displays to each second.

Males of this species when possible seem deliberately to mount a slight elevation to display, sometimes several inches from their holes. When a female is attracted the display is speeded up, and additions made, as the following field note shows: "On February 19 a female was obviously attracted directly to a male as soon as he came out of his hole six inches away and began to display. He became aware of her and speeded up his tempo. She circled him at a distance of several inches, then drew nearer. He seemed to be almost overcome with excitement, thrust his minor side down his hole, and made one last violent gesture with his major cheliped, his

major ambulatories meanwhile stretched straight out, clear of the ground, absolutely rigid but quivering from their bases. The position was held perhaps a second, then he vanished down the hole. The female followed him at once, without the slightest hesitation." This procedure was typical when males attracted the attention of females; sometimes the latter emerged after a few seconds and wandered off, the males meanwhile emerging and resuming feeding and moderate display. More often neither crab emerged at all soon, in two observations not before the tide covered the holes, two hours later. As in other species, however, compared with the almost incessant display at this season of the thousands of males in the area, the number of females each day which followed the males down their holes, presumably to mate, is exceedingly slight.

The entire display, with its exceptional speed, continuity, and especially in the development of the phase in which the cheliped is vibrated against the ground, represents the highest development yet found of this type of display, in which rapping of the ground, after the gesture with the cheliped, is involved. It was found to a lesser degree in *U. batuenta* and *U. inaequalis*.

Breeding: More than three-fourths of the adult females taken, all in February, were ovigerous at La Boca, Balboa. Young crabs of both sexes were relatively rare. The eggs, which measure .24 mm. in diameter after being preserved in alcohol, number between 1,200 and 1,800.

Growth: The young of this species have most of the distinguishing characteristics of the adult well developed, except for the oblique ridge inside the major palm; the large cheliped in the smallest taken, however, is already unmistakably typical of the species.

Affinities: This species is related most closely to *U. batuenta*, although its major cheliped is distinctly different from that of any known species. The large, isolated tooth in the outer, lower corner of the orbit serves as a convenient mark of distinction from related forms when the large cheliped is missing. The females are easily distinguished from the similarly shaped females of *U. oerstedii* by the lack of pile on the carapace, and from those of *U. batuenta* by the much deeper manus of the chelipeds, the somewhat produced orbital angles and by the little projecting lower borders of the orbits, with the external corners deeply excavated.

Range: Puntarenas, Costa Rica, to Old Panama, Panama.

Local Distribution: The great majority of the 201 specimens in the collection were taken in open mud flats of the deepest, stickiest type. A few were taken among the unshaded outpost shoots of the mangroves. At La Boca (Balboa) and at Old Panama, thousands of them were seen displaying daily, out in the mud, as far as the eye could see.

Material: Male holotype, Cat. No. 4123, La Boca, Balboa, Canal Zone; 7 male and 7 female paratypes, Cat. No. 4124, La Boca, Balboa,

Canal Zone; 113 males and 69 females, Cat. No. 4125, La Boca, Balboa, Canal Zone; 3 males and 1 female, Cat. No. 381,138, Puntarenas, Costa Rica. Seen but not collected at Old Panama, R. de P.

This species is named *saltitanta* because, in displaying, it dances with such tireless energy.

Uca beebei sp. nov.

Text-figs. 4P, 5; Pl. IV, Fig. 16; Pl. V, Fig. 20; Pl. VI, Fig. 27.

(See also pp. 149-151, 153-157, 159, 166, 167, 169).

Reference: *Uca stenodactylus*, Rathbun, 1917, p. 417 (part.); pl. 152, fig. 3; pl. 153. Not *Gelasimus stenodactylus* Milne Edwards & Lucas, 1843.

Diagnosis: Close to *U. stenodactyla*, but differing in the following characters: grows to 8 mm., not 9; regions of carapace scarcely swollen, little delimited; sides of carapace much less steeply inclined; ambulatories less slender in both sexes (width of merus of third ambulatory on minor side of male about two-fifths of length, not a fourth to a third); tips of minor chelae not overlapping; projecting spoon-tipped hairs on merus of second maxilliped 100 to 140, not 160 to 250; shelf replacing arm of abdominal appendage slanting toward base of appendage, not horizontal or with rudimentary arm; deep purplish-brown color on lower inner surface of major cheliped usually persisting for at least several years in alcohol, never present on *stenodactyla*.

Description: Moderately small species. Carapace strongly convex, semi-cylindrical in lateral view, widest at orbital angles or behind; surface smooth, naked, regions scarcely delimited or separately swollen; H-form depression very slight.

Antero-lateral margins slightly sinuous, slanting slightly outward, about half as long as width of front behind eyes. They then turn inward and backward in the usual concave ridge as far as level of middle of cardiac region. Sides of carapace descending only moderately steeply, concave, usually slanting slightly outward. Front between posterior margins of eyestalks about one-fourth or less width of carapace, its lower margin invisible; marginal ridge obsolescent. Upper margin of orbit sinuous. Eyebrow broad, about as wide as adjacent portion of eyestalk, little inclined. Lower orbital margin moderately projecting, with crenulations throughout, strong except internally. Suborbital regions naked except for one, or sometimes one and a half, rows of hairs immediately behind orbital margin. Third to sixth abdominal segments in male incompletely fused.

Spoon-tipped hairs on merus of second maxilliped moderately numerous, arranged in about 11 to 13 rows on inner fifth or quarter of merus, throughout its distal half. Those which are nearest the longitudinal center of the merus are so short as to be difficult to count; excluding these, counting only those which project beyond the inner margin, a total of between 100 and 140 is reached, 100 having been found in a small, ovigerous female, 130-140 in a large, non-oviger-

ous female, and about the same number in large males. Ischium of third maxilliped with median groove represented by a marginal indentation.

Minor chelae about once and a sixth as long as palm, usually coarsely serrated or toothed in middle portion, though rarely (including in the holotype) the serrations are low and appear worn. Usually, however, the region has three or four large teeth in the middle of each chela, flanked by fine serrations, which articulate almost or completely, leaving a small gape only proximally and, sometimes, distally. The corneous tips, however, are slightly dilated and articulate well. Oblique row of hairs along inner margins sparse except for distal brushes. Additional interrupted rows of sparse hairs as follows: two on or near dorsal profile of dactyl, one on external side of pollex, near ventral profile, sometimes obsolescent.

Large cheliped of male with arm and wrist moderately rugose externally; short pile inside dorsal half of carpal cavity, and between bases of chelae. Hand about two-thirds or more as broad as long. Upper surface rounded, bent over proximally to bound carpal cavity sharply; lower margin marked by elevated line of microscopic, close-set granules. Entire upper and outer surface covered with moderately fine, close-set low tubercles, largest dorsally. Inner, lower, proximal part of major palm, near ventral profile, roughened with microscopic granules, not in special linear formation, which are opposable to a row of almost equally fine granules on carpus of first ambulatory on major side; traces of another row on distal end of merus of first ambulatory.

An oblique tuberculated ridge on inner side of manus of major cheliped extending in a curving line from close to ventral profile to carpal cavity, and continuing upward toward dorsal margin. Below cavity the tubercles are large, regular, close-set in a single line though sometimes flanked by a few small tubercles; above they tend to be in double lines, grow smaller, and the ridge dies out in a cluster of low tubercles which fills in the space between it and the dorsal profile. Carpal eminence scarcely developed. A row of strong, close-set tubercles arises opposite middle of dactyl base and continues down and out along pollex, close to prehensile edge, the tubercles dwindling in size and becoming a mere elevated line which continues to tip. There is no additional row of tubercles paralleling base of dactyl on inner distal end of palm.

Major dactyl slender, about once and a third times as long as palm, tuberculated proximally on dorsal surface, almost straight, curving only slightly downward to overlap pollex distally. Pollex about equally slender, straight or slightly sinuous. Gape moderately wide, with many small, low, tuberculous teeth, of which two are usually enlarged, one in proximal half of dactyl, the other half way to tip of pollex. A row of small tubercles close to and parallel with prehensile edge of outer side of dactyl, dying out on distal half. This is represented on the corresponding part of the pollex by about four irregular rows of slightly enlarged tubercles basally,

around proximal end of gape, which continue out on pollex as much reduced granules near prehensile margin and gradually die away distally.

Merus of ambulatories moderately enlarged in both sexes, that of third ambulatory on minor side in male extending about a quarter of its length beyond antero-lateral margins when laid forward. Ambulatories on major side more slender, as in *U. stenodactyla*. In males and females, width of third merus is about two-fifths of its length.

Abdominal appendage of male slender, strongly bowed, tapering; arm absent, represented only by a row of bristles arising from a shelf slanting obliquely toward base of appendage in its distal ninth.

Measurements: Male holotype, length 7.4 mm., breadth 10.4 mm., base of manus to tip of pollex, 19.2 mm.; 8 male paratypes, lengths 3.1 to 7.8 mm.; 4 ovigerous female paratypes, lengths 4.8–5.3 mm.; 4 non-ovigerous female paratypes, lengths 2.6–7.9 mm.; 6 young, questionably referred to this species, lengths 2 to 2.5 mm. The 98 other specimens in the collection are all of intermediate size.

Color: Displaying males, observed through binoculars: anterior part of carapace brilliant iridescent green, posterior part gray. Outer side of major manus above, bright ochre to rosy pink; fingers white outside and in, sometimes yellow basally; lower sides of merus, carpus and manus externally, and lower inner side of manus as well, dark, rich plum purple; this characteristic color alone will identify the species from a distance. Inner side of merus pearl gray; upper inner side of manus ochre to pink, changing to pearl gray farther down, above plum purple area. Minor cheliped whitish. Coxa and basal part of merus of major ambulatories bright plum both anteriorly (ventrally) and posteriorly (dorsally); corresponding parts on minor side greenish; rest of ambulatories gray, like posterior half of carapace. Color fades especially quickly when crab is captured.

Females: Mottled or spotted dark on grayish-brown.

Display and Mating: All four pairs of ambulatories are left on the ground during display, and there is no added elevation of the body, which is normally held fairly high, except in specimens living in the mud; these stretch upward a bit with each display. However, in all the carapace is usually tilted slightly up and back with the effort of lifting the cheliped. At the start of the display, with the cheliped flexed in front of mouth, held clear of the ground, the carpo-manus joint is lifted. The cheliped is then straightened diagonally upward and outward describing a slight forwardly directed arc. It is then brought down without pause to position in a straight line, with a definite jerk. The general effect is of an emphatic beckoning. The movement is fast, about two to the second, and is usually repeated about four times without a break in the rhythm. The minor cheliped at the same moment generally makes an incomplete outward and inward

movement; when the crab is strongly excited through the attention of a female, this movement of the minor cheliped is complete and vigorous. Also, when displaying before an interested female, the male frequently turns his back, and revolves before her; since by this procedure the brilliant iridescent green of the anterior part of the carapace is shown, as well as the bright plum *posterior* (dorsal) parts of the ambulatory meri—parts which are not brightly colored in the other species where display was observed—it seems that this revolving is a definite part of display. Fingers are held slightly open, parallel, during each series of displays. The crab may stand close to his burrow and perform, or take a few steps in either direction.

As usual, when a female is interested, the whole display becomes swifter and more vigorous. The female must give some sort of signal when she is ready to follow the male, although I have never been able to see what this is, because suddenly, after seconds or minutes of display, the male without warning will vanish down his burrow, and in the perhaps half a dozen cases where I have seen courtship reach this stage, excluding the exceptions noted in the following paragraph, the female without hesitation followed after. The usual procedure thereafter is for one or both crabs to emerge briefly, then for both to disappear into the hole of the male and stay there, so far as I saw, until the succeeding tide.

Several times, however, I have watched the progress of a female wandering more than 10 feet from her own hole, and showing interest in the displays of a number of males, one after the other. One of these females, for instance, wandered across five feet of territory, crowded with both males and females, electrifying every male she came near into giving a vigorous display. In each case she paused and allowed matters to reach the point where the male, with a final excited flourish of his cheliped, vanished down his hole; then, instead of following him, she merely looked down into the hole, or literally stuck her eyes into it, then at once backed out and wandered on to the next male, who promptly paid her similar court. After she had crossed these five feet, she turned and came back toward the middle of the area by a slightly different route. Here she finally followed a male into his hole, after the usual preliminaries. He was not especially large or bright, though fully adult and with a well made shelter (see below). She stayed below about five minutes, then emerged momentarily, and descended again. After two minutes more they both came up, but descended again immediately, and this time they were both still down when I ceased observations, half an hour later, when the tide was almost covering the hole.

As in *U. stenodactyla*, actual pairing was observed at the surface. I was photographing another species at the time, and so missed the beginning of the mating, which was on the ground beside me, at the mouth of the female's

hole. As in other species, they were sternum to sternum, the female supporting most of the weight, the male slightly above her. His first two ambulatories grasped her body in front of her first ambulatories; his minor cheliped resting on her carapace behind her eyes; his major cheliped clearing her, held quietly. Both were stroking each other lightly with their ambulatories, but less actively than in *U. stenodactyla* at a similar stage. After about a minute they became perfectly quiet except for the quivering of their abdomens. After less than two minutes the female slipped down her hole, while the male moved three inches away toward his own and started feeding. It seems likely that, in this and other species, it is usual for mating to take place in the hole of the male, but that when he has come to the female, and interested her sufficiently near her hole, they mate outside, since he would not be able to descend the smaller opening.

The following instance of precocious and somewhat irregular behavior was observed in a male which does not appear to be more than about two-thirds grown. He had erected a well built shelter (see below) 15 mm. high, above a hole 7.5 mm. wide, which proved later to go four inches straight down and then three inches obliquely, after a sharp turn. His color was poorly developed. He was feeding and displaying three inches from his hole when a large female passed (7.3 mm. long, while he measured 6.2 mm., with a definitely underdeveloped major cheliped). He stopped feeding instantly, raced to the mouth of his hole, apparently much excited, and displayed frantically for three minutes, facing her with the large cheliped turned partly toward her, so that some of his back showed during display, without revolving. She came closer. He descended his hole, and she followed at once. He remained down five minutes, then emerged momentarily and descended. After five minutes more he again emerged, and this time began displaying and feeding again. After a few minutes he again descended. This routine continued for 25 minutes, and since the tide was approaching, I dug them up. The resumption of display after the presumable winning of a mate may be interpreted either as a use of display in defiance to other males, or as simply the irregular behavior of immaturity. It was not observed in adults either of this species or of others: once a female had entered the hole of a male, he did not display any more at least during that particular low tide.

Shelter: Of the three species, *U. beebei*, *U. latimanus* and *U. terpsichores*, which were observed to build shelters above their holes, the present species, *U. beebei*, has the habit least well developed. This primitive development is indicated both in the variable and relatively small and poorly constructed forms of the shelters, and in the apparent erraticalness with which they are erected. Sometimes they are well formed hoods arching over the hole, more often they are scarcely more than oblique and slightly concave turrets—a sort of “leaning towers”—and sometimes they are only tapering heaps of

sandy mud scarcely taller than the builder. Young males often start building, but do not finish. Even adults may take several hours to complete a shelter, working only sporadically, and often displaying for some time before starting operations. Furthermore, although they are built only by displaying males, not every displaying male builds a shelter; the ratio on most days at La Boca proved to be about one in ten. The exception to the latter proportion was when, on some days, a wave of shelter-building seemed to sweep a particular section of the colony. The males without shelters displayed as vigorously as those with perfect turrets; size and coloration of the crab are not involved; and I have seen females descend the holes of males with or without turrets, apparently without any preference at all. The male I saw actually pairing at the surface had no shelter. A given individual seems to build a shelter at least several days in succession, although I have not yet concluded satisfactory observations on this subject.

In general, a major wave of shelter building seemed to be prevalent in the colony on the right side of the beach at La Boca in the first two weeks in February, then, while it died down there, to rise to full swing in the colony on the left beach in the last two weeks of the same month. Furthermore, although this species was found at La Boca, and farther along the coast at Panama City and Old Panama both on the firm muddy sand and out in the true mud, at least within 15 feet of shore, turret building is chiefly confined to the individuals on the muddy sand. A few males, however, living in the mud erect poor ones; the semi-liquid consistency of this building medium of course militates against its use.

The method of building is the same as in other species, material being scraped by the major ambulatories at a distance from the mouth, carried back to the hole by the first two major ambulatories, and heaped up while the minor side of the crab rests in the mouth of the hole. (See p. 157).

Breeding: Many ovigerous females were seen at La Boca and Panama City in February. The collection contains five, four from La Boca, and one from Puntarenas, Costa Rica, also taken in February. The magenta eggs, measuring .24 mm. in diameter when preserved in alcohol, number about 1,500.

Young: The young are distinguishable from those of *U. stenodactyla* by their notably more swollen ambulatories. In both species specimens under about 3 mm., have very few—only about 25—spoon-tipped hairs on the merus of the second maxilliped. Possible confusion with members of the group of species containing *Uca oerstedii* and *Uca saltitanta* is eliminated variously by the lack of pile on the carapace (so characteristic of *U. oerstedii*), by the broad eyebrow, by the well developed crenulations on the lower orbital margin, and by the several enlarged teeth alone or among the serrations of the minor cheliped. These teeth, combined with the very slight gape, distinguish them at once from the

group containing *U. latimanus*, all of which have the minor chelae widely gaping. The moderately narrow front and beginnings of a broad carapace strongly arched, distinguish them easily from the young of more distantly related species.

Affinities: This species is very close anatomically to *U. stenodactyla*; the differences have already been listed under *Diagnosis*. In coloration and habits, however, it differs greatly, the colors being very different and less bright—iridescent green, plum, ochre and gray instead of blue, white, pink and red; these relatively dark colors, however, are equally striking in their own way. The beckoning portion of the display is fundamentally similar, although it is twice as fast, has a jerk, and differs in the characteristic preliminary raising of the carpo-manus joint; also, *U. beebei* revolves before a female, which *U. stenodactyla* does not. On the other hand, *U. beebei* never pursues females or races along with one encircled by the major cheliped, as does *U. stenodactyla*. Finally, displaying males of *U. beebei* sometimes build shelters, those of *U. stenodactyla* never, although adult females of the latter species sometimes by similar methods raise high walls around their holes. The colonies of the two species are often intermingled, one species being usually dominant, when *U. beebei* is found on muddy sand. *U. stenodactyla*, however, unlike *U. beebei*, is never found in pure mud.

Range: From Corinto, Nicaragua, to Old Panama, R. P.

Local Distribution: The 115 specimens were found principally on gravelly muddy sand, or muddy sand, but were common also on mud flats and, rarely, among mangrove shoots which were mostly unshaded. Six very young specimens of slightly questionable identity were found in the mud, among adults, close to a muddy sand beach.

Remarks: An examination of the specimens at the United States National Museum which were referred by Miss Rathbun (1917) to *U. stenodactylus* shows that Cat. Nos. 32321 and 32322, Boca del Rio Jesus Maria, and Puntarenas, Costa Rica, respectively, should be referred to *U. beebei*. It is one of these specimens that is illustrated in her monograph (pl. 152, fig. 3 and pl. 153).

Material: Male holotype: Cat. No. 4129, La Boca, Balboa, Canal Zone; 8 male and 8 female paratypes, Cat. No. 4130, same locality; 39 males and 25 females, Cat. No. 4131, same locality; 15 males and 3 females, Cat. No. 4133, Bellavista, Panama City, R. P.; 7 males and 3 females, Cat. No. 4134, Old Panama, R. P.; 1 male, Cat. No. 381,150, Bahia Honda, R. P.; 2 males, 3 females, Cat. No. 381,149, Puntarenas, Costa Rica; 2 males, Cat. No. 381,148, Corinto, Nicaragua; 6 young, Cat. No. 4132, La Boca, Balboa, Canal Zone, probably belong to this species.

This species is named in honor of Dr. William Beebe, Director of the Department of Tropical Research, New York Zoological Society, and of its Eastern Pacific Expeditions.

Uca stenodactyla (Milne Edwards & Lucas, 1843).

Text-figs. 4Q, 5. Pl. IV, Fig. 15; Pl. V, Fig. 21; Pl. VI, Fig. 28; Pl. IX, Figs. 41, 42.

(See also pp. 149–154, 156, 158–160, 166, 167, 169).

References: *Gelasimus stenodactylus* Milne Edwards & Lucas, 1843, p. 26; 1847, pl. 11, fig. 2.

Uca stenodactylus Rathbun, 1917, pp. 416–7, part.; not pl. 152, fig. 3 or pl. 153.

Range: Gulf of Fonseca, El Salvador, to Valparaiso, Chile. Reported from Brazil, probably erroneously, by Milne Edwards.

Local Distribution: Found on tidal flats and protected shores composed of sandy mud which is midway in consistency between the extreme softness and stickiness of clayey mud and the sand of true beaches. The colonies are large as a rule and occur near, but not among, mangroves.

Supplementary Specific Characters: Spoon-tipped hairs on merus of second maxilliped numerous, arranged in about 15 to 25 closely packed rows on inner quarter or third of merus, throughout its distal five-sixths. The spoon-tipped hairs arising nearest the longitudinal center of the merus are so short as to be difficult to count; excluding these—that is, counting only the spoon-tipped hairs which project beyond the inner margin—a rough total of about 160 to 250 is reached, the lower figures being typical of the smaller crabs. Woolly hairs sparse. Ischium of third maxilliped with median groove represented by a shallow, hairless depression extending about half length of ischium, parallel to inner groove; entire maxilliped bulging somewhat outward.

Minor chelae more than half again as long as palm, usually coarsely serrated or toothed in middle third. This portion includes several enlarged teeth on each edge; sometimes the dactyl serrations consist only of two to four good-sized teeth; rarely the serrations appear low and worn. In all cases, however, there is a gape only in the non-serrated basal portion and, sometimes, beyond the serrations distally, since the teeth and serrations almost or perfectly articulate. Distal part corneous but not dilated, tapering, the tips not articulating, that of dactyl falling inside that of pollex. Oblique row of hairs along inner margins sparse except for distal brushes. Additional rows of sparse hairs as follows: two on or near dorsal profile of dactyl, one on external side of pollex, near ventral profile.

Eyebrow broader than adjacent portion of eyestalk. Lower orbital margin crenulated throughout, though weakly internally. Suborbital region naked except for a short row of hairs immediately behind crenulated margins.

Merus of ambulatories scarcely dilated; even in female that of third ambulatory reaches a fifth to a quarter of its length beyond orbital angle when laid forward. Breadth of merus of third ambulatory on minor side of male about a fourth to a third of its length.

Abdominal appendage moderately slender, tapering distally. Arm absent, represented only by a few bristles arising from a horizontal shelf, or, rarely, produced as a rudimentary stump, at

the beginning of about the distal eighth or ninth of appendage.

Measurements: The 72 specimens taken include the following extremes of length: largest male, 9.1 mm.; largest females (ovigerous), 5.1 to 6 mm.; smallest specimen 1.6 mm.

Color: Displaying males observed through binoculars: carapace iridescent gray blue or violet blue anteriorly, white or blush pink posteriorly. Outside and inside of merus and carpus of major cheliped yellowish-white to white; outer lower part of manus and all of outer side of pollex bright lilac pink; upper part of manus and dactyl white or pinkish-white; inside of manus pale salmon pink; inside of both chelae flame orange in brightest, in palest pale salmon. Minor cheliped with merus and carpus yellowish, manus and chelae pink or salmon. Eyestalks lemon yellow. Buccal and pterygostomial regions greenish or yellowish-white to pure white. Ambulatories anteriorly (ventrally) flame scarlet, the merus brightest; posterior (dorsally) pale rosy, the last two legs dullest. As courting males brighten in the sunlight from dull browns and buffis resembling female coloration, after emergence from their holes, the first change is the appearance of the flame color. This shade spreads from the inside of the chelae to the inside of the manus, then around to the outer lower part of the manus in the form of lilac pink; the carapace gains last its full brilliant, iridescent, violet blue anteriorly, and white or blush pink posteriorly.

Females and young, grayish-brown, mottled or spotted; the ambulatories banded gray and brown; manus and dactyls of chelipeds white to violet; eyestalks yellow in largest.

Display and Mating: Body held consistently high during a series of displays without special stretching. Large cheliped starts from folded position, held well clear of ground, opens slowly outward and only very slightly upward, so that at end of gesture it is only a little way above eye level; then, without a break in the rhythm, it is folded inward and drawn down into place. The small cheliped meanwhile makes a small, corresponding, outward gesture. Chelae of both sides are held slightly open. A few rapid running steps are usually taken during each display, which itself is slow and measured, with no downward jerk, and lasts slightly more than one second. Every few minutes a wave of excitement sweeps over half a dozen or so adjacent males—a wave which is not to be confused with the fear “alert” signal, in which the claw is at once folded and a swift return made to the hole. In the excitement under consideration, a female is always the stimulus: either one has appeared at her hole close by, or has stopped feeding and looked around, or has progressed from a distance into the neighborhood of the interested males. She is not necessarily large (I do not say “not necessarily adult,” since very small females have been observed carrying eggs); I have never seen the response evoked by an ovigerous female. At

this time the excited, adjacent males raise their large chelipeds much higher than usual, holding them, when much excited, almost perpendicularly above their heads, and race several inches to one side and back again, either holding the cheliped motionless, or, sometimes, waving it slightly, and with the fingers spread wider than usual. Sometimes the cheliped is stretched straight out to the side instead. When the female pays no attention, passes by, or resumes feeding, the male returns to the original, less excited, beckoning type of display, which is often accompanied by feeding.

Often several males, galvanized in the above fashion, chase a female some distance, while she doubles and dodges skillfully. Sometimes one will manage to encircle her with his large cheliped, holding her loosely, without touching her, and race along with her, apparently trying to direct her toward his hole, while she endeavors to duck out from under and escape, although she never seems actually frightened and the male never seems to make a serious effort to hold her. On all of the numerous occasions I have watched this performance, it has always ended with the female's escaping and racing down her own hole. Sometimes brief duels result between males who have been chasing the same female. The whole performance seems to be at the least an expression of excess energy, rather than any serious attempt at mating, and may even be interpreted as an approach to sheer sexual play or sport.

Actual mating, on the surface, was observed twice; on about three or four other occasions a female was induced by the male to follow him, after violent display at an increased tempo, down his hole; she stayed for varying lengths of time, from ten minutes to indefinitely, the tide covering the hole in the latter cases before either crab emerged.

The first surface mating seen was on February 14, at La Boca, and was particularly interesting because of the actions of the female. The latter, along with others close by, were for the first time observed to be building high thick walls of pellets around their holes. High tide came at noon; the sky was about two-thirds clear. Starting about an hour and a half before low tide a number of the largest females swiftly began to build walls. In each case the muddy sand was scraped from a distance, usually about two inches, beyond the mouth of the hole, as with the male shelter builders (*U. beebei*, *U. latimanus* and *U. terpsichores*), not brought up from below as with the females and young of *U. latimanus*, which stop up the mouth of the burrow with a small dome, presumably against the heat of the sun. The highest of the *stenodactyla* walls was about two-thirds of an inch; some were lower but thicker, being an inch and a half across the outer circumference. By dead low tide all of the females concerned had entered and sealed themselves in with the tossing of a few pellets across the top. No ovigerous females were seen building walls, and no small ones. The males seemed to be paying especial attention to the builders during operations.

The copulation mentioned above occurred as follows: An adult male, large and moderately brightly colored, displayed before a female who watched attentively from near her just-completed wall. They then both walked slowly over to it. When they reached it, she climbed halfway to its top, clinging to it, while the male remained at the bottom, reached up with his minor middle ambulatories, and stroked her adjacent ambulatories gently. Then they both climbed to the broad top of the wall, and he spent almost a minute stroking her legs and carapace, very gently, with both major and minor ambulatories and with his minor cheliped; occasionally she stroked him in return. She made no effort whatever to descend into her hole. Finally they both very deliberately straddled the wall, which gave them excellent support, sternum to sternum, the posterior part of the carapaces not quite touching the wall. The male clasped the female about the body, between her first and second ambulatories, with his first and second, supporting himself on the sides of the wall with his last two pairs. He was slightly higher than she; the major cheliped was not used at all, but rested folded just above her eyes, not touching her. The minor cheliped rested lightly on her carapace, behind her right eye. Her abdomen was (I think) underneath, and his apparently bent back, although since her back was toward me, it was difficult to make sure. At first he continued to stroke her legs a little every few seconds, very lightly, with the two pairs of legs which held her. Then they both remained absolutely motionless for about two and one half minutes. Then, although they had not been alarmed or disturbed, she swiftly but gently disengaged herself and slipped down her hole. The male made no effort to follow but descended to the ground, swinging his abdomen down and back into place three or four times as he did so; he then began feeding normally at once. The female never reappeared, except to close her hole with a plug within the next three-quarters of an hour. It was then just about dead low tide, the time of greatest activity in the colony. The male definitely stood guard at first, shooing off two other males who came from time to time to the top of her wall and peered down. Several times the guarding male mounted the wall, straddling the hole, and threatened off aggressors by lunging at them with his large cheliped, in motions quite different from the display "beckonings." He never made any effort, to descend the female's hole.

A second mating was observed on February 28. In this case the male had been courting the female for at least an hour, catching her attention with display, approaching her hole, and getting as far as stroking her. She had not built a wall, and each time he approached her slipped down her hole after having allowed several strokings. Finally mating occurred, at the mouth of her hole, the position being much as in the pairing previously described, and I secured several photographs (Plate IX). This time the abdomen of the female was clearly outside that of the male.

Since I was busy with the camera, I did not count seconds to time the copulation, but it seemed to last two or three minutes, as in the other case. As before, the female ended it by going down her hole, which she eventually plugged up.

As in other species, I believe that the more usual method of mating is for the male to induce the female to follow him down his hole (see p. 157). I have no idea of the significance of the walls erected by large females, which, after the first observations of them, were on some days absent from the colony and on other days fairly numerous; weather conditions did not seem to be involved.

A strange episode was the deliberate destruction of the wall of an exceptionally large female by an immature male. He had just started to stroke her legs with his, after an incomplete, brief, very elementary display, to which she appeared to pay no attention. She was on the side of the wall, he at the base. At this point she climbed to the top and disappeared down her hole. He did not try to follow, but at once began systematically tearing the wall down, using chiefly the ambulatories of the minor side, and did not stop until it was well levelled and trampled flat, the operation lasting about five minutes. Then he moved off to his own hole and began feeding unconcernedly. After a few minutes she emerged and began feeding too. She showed no evidence of any emotion, or even realization that the wall was gone, and did not rebuild before the tide covered her hole.

Breeding: Ovigerous females were fairly common in the colony at La Boca in February. Three were captured at Corinto, Nicaragua, in January. The eggs, which measure between .25 and .27 mm. in diameter after having been preserved in alcohol, number from about 1,000 to 1,500. There were many very young specimens at Corinto in January, but not at La Boca in February.

Growth: Although the major chelipeds are as usual short and specifically uncharacteristic in the young, and the carapace relatively flat and narrow, the broad eyebrows, moderately narrow front, minor cheliped strongly toothed in the central area, and second maxillipeds with abundant spoon-tipped hairs, make them difficult to confuse with the young of any species except, possibly, those of *U. beebei*, of which very young specimens have not been identified with certainty. Comparable specimens of the two species measuring 2.7 mm. in length are readily distinguishable by the more slender ambulatories in *U. stenodactyla*. Specimens of the latter under 2 mm. long have only about 25 spoon-tipped hairs, but these are strongly developed. Young between 1.6 and 3 mm. long ran freely in and out of the burrows of larger crabs, both of their own species and of *U. stylifera*, at Corinto. In young males the major cheliped is the first part of the crab to show adult coloration, turning gradually pinkish, with the tips of the claws taking on color last; the carapace changes next from the

mottled phase, becoming blue and white; and the ambulatories are the last to be transformed, changing from the banded coloration to buff and scarlet.

Burrows: The burrow of a large male extends from two to six inches straight underground, then turns with a short crook at the end, or else it may continue diagonally from the turn to a total of about nine inches underground. A smooth, clean area is usually left for several inches or more around the hole, the size of this display ground depending on the extent of crowding in the colony.

Remarks: The specimen illustrated by Rathbun (1917, pls. 152, 153) should be referred to *U. bebei* (see p. 195).

Material: A total of 72 specimens was taken from Corinto, Nicaragua; Port Parker and Golfito, Costa Rica; La Boca, Balboa, Canal Zone; and Panama City, Panama. Cat. Nos. 381,145, 381,146, 381,147, 4127, 4128.

Uca helleri Rathbun, 1902.

Text-figs. 4R, 5.

(See also pp. 149, 161, 166, 167, 169).

Reference: *Uca helleri* Rathbun, 1902, p. 277, pl. 12, figs. 3 and 4; 1917, p. 415, pl. 151. Boone, 1927, p. 278, fig. 98.

Range: Galápagos Islands.

Supplementary Characters: Spoon-tipped hairs on merus of second maxilliped moderately numerous, arranged in about 12 to 15 or more rows on inner fifth or quarter of merus, throughout its distal half. The spoon-tipped hairs arising nearest the longitudinal center of the merus are so short as to be difficult to count; excluding these—that is, counting only the spoon-tipped hairs which project beyond the inner margin—a rough total of about 130, in a female 7.7 mm. long, is reached. Woolly hairs moderately sparse. Ischium of third maxilliped with median groove represented by a shallow, hairless, distal depression.

Minor chelae almost once and a half times as long as manus, widely gaping to the abruptly tapering, corneous, articulating tips. Prehensile edges armed only with rudimentary, fine serrations, sometimes almost lacking. An oblique row of rather long hairs along inner side, sometimes interrupted distally, but resumed as the usual long brushes distally. Traces of two or three additional rows, represented only by a few stubby hair bases, near profiles of both dactyl and pollex.

Eye-brow about as broad as adjacent portion of eyestalk. Lower orbital margin well crenulated throughout. Suborbital region naked except for a row of hairs immediately behind crenulated margins.

The abdominal appendage of a young male (3.7 mm. long) is moderately slender with a slim, rudimentary arm arising at about the distal fifth.

Material: The four specimens at present in the collections of the Department of Tropical Re-

search were taken at Tower Island, Galápagos, by the *Arcturus* Oceanographic Expedition in 1925. They consist of two males, 3.2 and 3.7 mm., and two females, 4.2 and 8 mm. in length. They have already been recorded by Boone (1927, p. 278). The male illustrated by her (p. 279, fig. 98) has been mislaid.

Uca crenulata (Lockington, 1877).

Text-figs. 4S, 5.

(See also pp. 149, 151, 166, 169).

References: *Gelasimus crenulatus* Lockington, 1877, p. 149.

Uca crenulata, Rathbun, 1917, p. 409, pl. 146.

Range: Previously known from San Diego, California, to Mazatlan, Mexico. The present collection extends the range south about 4 degrees to Tenacatita Bay, Mexico.

Local Distribution: Found on the muddy shore of a lagoon.

Supplementary Specific Characters: Spoon-tipped hairs on merus of second maxilliped numerous, arranged in about 12 to 15 rows on inner fifth or quarter of merus, throughout its distal half, and numbering roughly 175 to 200 in large specimens (borrowed from the American Museum of Natural History), and about 125 in the smaller males (about 6 mm. long) in the present collection. Woolly hairs sparse. Ischium of third maxilliped with median groove represented by a shallow, hairless, distal depression.

Minor chelae about once and three-fifths times as long as manus, widely gaping to the abruptly tapering, corneous, articulating tips. Prehensile edges armed with weak serrations. An oblique row of hairs along each inner surface, ending in a short brush distally; another row of longer hairs along inside of each prehensile edge. Traces of two or three rows of stubby, microscopic hairs near dorsal profile of dactyl and ventral profile of pollex, respectively.

Eye-brow almost as broad as adjacent portion of eyestalk, scarcely inclined. Lower orbital margin crenulated throughout. Suborbital region naked except for a row of hairs immediately behind crenulated margins.

Abdominal appendage slender, with well developed, slender arm arising about seven-eighths of the way to the tip.

Measurements: The three specimens taken consist of two males measuring 5.9 and 6.24 mm. in length, and one immature female, 5 mm. long.

Material: All were taken at Tenacatita Bay, Mexico. Cat. No. 381,151.

Uca limicola sp. nov.

Text-figs. 4T, 5; Pl. IV, Fig. 17; Pl. V, Fig. 22; Pl. VI, Fig. 29.

(See also pp. 149, 166, 169).

Diagnosis: Carapace semi-cylindrical in lateral view; front behind eyes slightly more than a quarter maximum width of carapace; orbits scarcely oblique; antero-lateral margin slightly

concave, followed by a sharp angular turn inward and backward; orbital angle acute, moderately produced. Minor chelae gaping moderately widely throughout length to articulating tips, feebly serrated. Oblique ridge inside palm of major cheliped present, strong in upper half; pollex tapering distally to a rounded tip, not obliquely truncate; several slightly enlarged teeth in each chela. Eyebrow slightly more than half width of adjacent portion of eyestalk, continued outward almost as far as orbital angle. Merus of second maxillipeds with about 100 to 135 spoon-tipped hairs. Abdominal appendage of male slender with well developed arm.

Description: A small species. Carapace with regions practically indistinguishable, including H-form depression; surface covered with widely spaced microscopic hairs.

Carapace strongly convex, semi-cylindrical in lateral view, widest at orbital angles. Antero-lateral margins concave, slanting slightly inward, about half as long as width of front behind eyes. They then turn inward and backward at a sharp angle, continuing in the form of the usual concave ridge as far as middle of cardiac region. Sides of carapace concave, scarcely converging. Front between posterior margins of eyestalks slightly more than one-fourth width of carapace; the distal part of its marginal ridge obsolete. Marginal line of front distinct. Upper margin of orbit sinuous, scarcely oblique. Eyebrow slightly more than half width of adjacent portion of eyestalk, moderately inclined, continuing outward almost to orbital angle. Lower orbital margin little projecting, crenulated throughout, the most internal crenulations, though small, being perfectly formed. Suborbital region naked except for a row of hairs immediately behind orbital margin. Third to sixth abdominal segments in male very incompletely fused.

Spoon-tipped hairs on merus of second maxilliped moderately numerous, arranged in about 10 rows on inner fifth or quarter of merus throughout its distal three-fifths, and numbering roughly about 100 to 135. Ischium of third maxilliped with median groove represented only by a marginal indentation.

Minor chelae about once and a sixth as long as palm, gaping moderately widely throughout length as far as the articulating, corneous tips; the latter are scarcely dilated and taper distally. Prehensile edges feebly serrated. Oblique row of hairs along inner margins of dactyl and pollex well developed, ending in long, thick brushes. Another pair of rows, on outside, close to their prehensile margins, also elongated distally, although not so much as inner hairs. Traces of four other rows, two near dorsal profile of dactyl and two near ventral profile of pollex respectively.

Large cheliped of male with arm and wrist granulated and finely rugose externally. Hand about two-thirds as broad as long. Upper surface of palm rounded, bent over proximally to bound carpal cavity sharply; lower margin marked by an elevated line of microscopic, close-set granules. Entire upper and outer surface covered with

moderately fine, close-set low tubercles, largest dorsally. Inner, lower, proximal part of palm, near ventral profile, roughened very slightly by a few microscopic granules; carpus of first ambulatory on major side similarly roughened with a very few minute granules.

An oblique tuberculated ridge on inner side of manus of major cheliped, strong throughout, the tubercles in a single line, continuing distinctly to upper margin. Carpal eminence moderately developed. A row of similarly strong tubercles arises close to dorsal margin at base of dactyl, continues obliquely downward, and dies out along pollex in a gradually obliterated line close to and paralleling prehensile margin. Across base of dactyl, distal to this first row, are several rudimentary tubercles.

Major dactyl slender, about once and a quarter times as long as manus, with only a few fine granules dorsally at extreme base, arched downward distally beyond tip. Gape wide throughout with very small, low, tubercular teeth, of which one in the proximal half of the dactyl and several more in distal half of pollex are enlarged. In addition there may be several slightly enlarged on the dactyl. On external side are two rows of microscopic granules close to and paralleling prehensile edges of dactyl and pollex, respectively.

Merus of ambulatories scarcely enlarged.

Abdominal appendage of male slender, with an obliquely truncate tip, and a well developed, slender, tapering arm arising about six-sevenths of way to tip.

Measurements: Male holotype, length 5.8 mm., breadth 9.2 mm., base of manus to tip of pollex 15.8 mm.; 11 male paratypes, length 3.6 to 6.6 mm.; 8 female paratypes (non-ovigerous), length 3.9 to 6.4 mm.

Affinities: *U. limicola* is most closely related to *crenulata* and *deichmanni*. The principal distinctions are indicated in the key. In the specialization trends shown in Group 5, directed toward increased arching of carapace and reduction of serrations and increase in gape of the minor chelae, the proposed new species is a perfect intermediate between *crenulata* and *deichmanni*.

Range: Known only from Golfito, Gulf of Dulce, Costa Rica.

Local Distribution: Found along the muddy bank of a slightly brackish stream.

Material: The 20 specimens consist of the male holotype, Cat. No. 381,152, and 11 male and 8 female paratypes, Cat. No. 381,153, all from Golfito, Costa Rica.

The name *limicola* is given to this species in reference to its occurrence in mud.

Uca deichmanni Rathbun, 1935.

Text-figs. 4U, 5; Pl. IV, Fig. 18; Pl. V, Fig. 23; Pl. VI, Fig. 30.

(See also pp. 149, 150, 153, 156, 166, 167, 169).

Reference: *Uca deichmanni* Rathbun, 1935, p. 52.

Range: Previously known only from the holo-

type, taken at Panama. The present collection was made between Port Parker, Costa Rica, and Old Panama, R. P.

Local Distribution: Found on very moist, gravelly, muddy sand, or on pure sand, often at the borderland between beach and mud flat, and often in the same type of terrain close to large, scattered stones. Burrows only about three inches deep.

Supplementary Specific Characters: The present material has been compared with the holotype at the U. S. National Museum and found to agree perfectly. In the light of these additional specimens, Miss Rathbun's preliminary description may be amplified as follows:

Diagnosis: Carapace semi-cylindrical in lateral view; front behind eyes about a quarter maximum width of carapace; orbits moderately oblique; antero-lateral margin concave, followed by a moderately sharp turn inward and backward; orbital angle acute, slightly produced. Minor chelae gaping widely throughout length to tapering, poorly articulating tips; edges feebly serrated. Oblique ridge inside palm of major cheliped present, weak in upper half; pollex obliquely truncate; only one enlarged tooth on chelae, located at beginning of middle third of dactyl. Eyebrow almost as wide as adjacent portion of eyestalk, dying out, except for an elevated line, less than three-fourths of way out to orbital angle. Merus of second maxillipeds with about 150 to 200 spoon-tipped hairs which are long enough to project beyond inner margin, and additional shorter ones. Abdominal appendage of male slender with well developed arm arising at distal eleventh.

Description: A small species. Carapace strongly convex, semi-cylindrical in lateral view, widest at orbital angles, regions fairly well indicated, due to their individual convexities; surface naked.

Antero-lateral margins concave, slanting slightly inward, less than half as long as width of front behind eyes. They then turn inward and backward at a broad, not strongly marked angle, in the form of the usual concave ridge as far as middle of cardiac region. Sides of carapace sinuous, slanting slightly either outward or in. Front between posterior margins of eyestalks about one-fourth width of carapace. Eyebrow slightly more than half as wide as eyestalk; margin of front distinct but weak. Lower margin of orbit strongly projecting, strongly crenulated throughout, the most internal crenulations, though small, being perfectly formed. Suborbital region completely naked. Third to sixth abdominal segments in male showing faint signs of partial fusion.

Spoon-tipped hairs on merus of second maxilliped numerous, arranged in about 14 to 20 rows on inner quarter or third of merus throughout its distal three-fifths and numbering roughly about 150 to 200, counting only those spoon-tipped hairs which are long enough to project beyond inner edge of merus. Ischium of third maxilliped with median groove represented by a very shallow, hairless depression on distal third.

Minor chelae about once and a half as long as palm, gaping widely throughout length to the slender, tapering, poorly articulating tips. Prehensile edges with feeble serrations barely distinguishable. Oblique row of hairs along inner margin of dactyl and pollex moderately well developed, ending in long, thick brushes. Another pair of rows, on outside, close to their prehensile margins, also elongated distally, although not so much as inner hairs. Traces of five other rows, three on upper, outer side of dactyl and two on outer side of pollex, near ventral profile, respectively.

Large cheliped of male with arm and wrist externally finely granulate on rugosities. Hand slightly more than two-thirds as broad as long. Upper surface of palm rounded, bent over proximally, to bound carpal cavity sharply; lower margin faintly cristate. Entire upper and outer surface covered with fine, close-set granules, larger dorsally; erosions mentioned in type description inconspicuous. Inner, lower, proximal part of major palm, near ventral profile, roughened very slightly by a few microscopic granules; carpus of first ambulatory on major side with no more than several minute granules for roughening.

An oblique, tuberculated ridge on inner side of manus of major cheliped, greatly elevated, strong and composed of a single row of tubercles as far as carpal cavity; beyond this it continues to dorsal profile as an irregularly double row of small, low tubercles, not at all elevated. Carpal eminence strongly developed. A row of distinct, moderate-sized tubercles arises close to dorsal margin at base of dactyl, continues downward and dies out along pollex in a gradually obliterated line close to and paralleling prehensile margin. Across base of dactyl, distal to this first row, is a line of four or five small but distinct tubercles.

Major dactyl slender, about once and a half times as long as manus, with only a few fine granules dorsally at extreme base, arched downward distally beyond tip of pollex, which is also slender, with the tip obliquely truncate. Gape wide throughout with numerous small, low, similar teeth except for one, much enlarged, about one-third of way to tip of dactyl. A row of small tubercles proximally close to prehensile edge of dactyl both internally and externally. A corresponding one on external side of pollex.

Ambulatories slender, the merus scarcely enlarged.

Abdominal appendage of male slender with a convexly truncate tip, and a well developed, slender arm arising at the beginning of about the distal eleventh.

Measurements: The 64 specimens taken include the following extremes of length: largest male, 6.4 mm.; largest female, 6.4 mm.; ovigerous female, 5 mm.; smallest male 3 mm.; smallest female, 3.1 mm.

Color: Displaying males observed through binoculars: carapace and dorsal (posterior) sides of ambulatories, brownish or dark gray. Outer

side of merus and carpus of major cheliped dark brown; outer side of manus and chelae dazzling pure white; inner side of merus and carpus magenta; inner side of manus and chelae violet rose, or, sometimes, ochre. Buccal and pterygostomian regions violet blue; subhepatic region bottle green. Ventral (anterior) side of merus of first three ambulatories yellowish.

Eggs magenta.

Display: During each display body is elevated as high as possible on all four pairs of legs. At beginning cheliped is flexed at right angles, parallel to front, covering front completely. Chelae are held slightly open, parallel to each other. With a swift movement cheliped is opened and raised with an upward and outward swing. At point of highest possible stretch it is held for an instant, exactly as in a Fascist salute, then lowered swiftly in the same plane in which it was raised. The display is repeated without pause; hence, unlike other species, the accent is at the peak of the elevation of the cheliped, not at the flexed position. During display, the minor cheliped remains flexed, or hangs motionless. A few steps in either direction may be taken during display, which is made at the rate of about two to the second. Twelve or fifteen displays may be made without pause.

Breeding: Ovigerous females were seen at Balboa, and in nearby regions in Panama, throughout February. Only one was captured. The eggs, which measure .24 mm. in diameter after having been preserved in alcohol, number about 2,000.

Affinities: This species is most closely related to *U. limicola*. The distinctions are indicated in the key.

Material: The 64 specimens in the collection were taken at Port Parker, Piedra Blanca, Uvita Bay, and Golfito, Costa Rica; at Bahia Honda, Panama City, and Old Panama, Panama; and at La Boca, Balboa, Canal Zone. Cat. Nos. 381,154, 381,155, 381,156, 381,157, 381,158, 4141, 4142, 4143.

Uca latimanus (Rathbun, 1893).

Text-figs. 2, 3, 4V, 5. Pl. VI, Fig. 33, Pl. VII, Fig. 36; Pl. VIII, Figs. 38, 39, 40.

(See also pp. 149, 150, 153-159, 161, 165-167, 169).

References: *Gelasimus latimanus* Rathbun, 1893, p. 245.

Uca latimanus, Rathbun, 1917, p. 422, pl. 157.

Range: La Paz, Lower California, to Tumaco, Colombia.

Local Distribution: Sandy-mud and muddy banks of fresh- and brackish-water streams and lagoons.

Supplementary Specific Characters: Spoon-tipped hairs on merus of second maxilliped exceptionally numerous, covering all except outer third of dorsal surface, found even on proximal part of inner margin, though flanked externally by the usual long and short slender-tipped hairs. The spoon-tipped hairs are arranged in about 45 or more rows in fairly regular quincunxial forma-

tion. Counting only those which arise near the margin and are long enough to project beyond it, a total of about 400 or more can be counted on a mature specimen. Woolly hairs moderate in number. Ischium of third maxilliped broad, smooth, strongly convex and practically naked, with median groove absent and even inner groove, though distinct, not deep.

Minor chelae about once and a half times as long as palm, gaping widely throughout length to the slender, tapering, corneous tips, which articulate poorly. Prehensile edges without a trace of teeth or serrations. Oblique rows of hairs along inner margin of dactyl and pollex poorly developed, except for distal brushes of long hairs. Other rows, all irregular and represented chiefly by several isolated, fairly long hairs, are found on both surfaces of both chelae.

Eye-brow about as broad as adjacent portions of eyestalk. Marginal line of front well developed. Lower orbital margin crenulated throughout, the internal crenulations small but distinct. Sub-orbital region naked except for one to three short rows of hairs, immediately behind crenulated margins.

Ambulatories short, in addition to the well known breadth of all segments. That of merus of third ambulatory on minor side of male is fully two-fifths of its length.

Abdominal appendage moderately slender, tapering little distally. Arm well developed, arising at about distal tenth of appendage.

Entire lower proximal inner surface of manus roughened by close-set granules, opposable to a conspicuous corneous ridge on anterior (ventral) surface of carpus of first ambulatory.

Measurements: The 59 specimens taken include the following extremes of length: largest male, 9.5 mm.; largest female, 8.6 mm.; smallest male, 4.5 mm.; smallest female, 3.1 mm.

Color: Displaying males observed through binoculars: carapace white, usually marked sparingly with slate or brown, but quite often pure, dazzling white. Major cheliped, except chelae, externally bright tawny, or tawny orange, sometimes with a salmon tinge. Inside of merus similar to outside. Chelae white both outside and in. Inside of manus and carpus less bright than outside. Minor cheliped bluish-white. Buccal, pterygostomian and subhepatic regions and all underparts bluish-white to pure white. Anterior (ventral) sides merus of first three pairs of ambulatories bright plum red, rest of anterior sides of ambulatories slate blue; posterior (upper) side of ambulatories white with slate or brown markings stronger and more numerous than those on carapace. The above coloration is acquired very gradually, in the sun, during and after completion of the shelter, the building of which follows feeding in the daily routine. At the earliest the coloration is acquired about two hours after high tide, and then only by crabs living high on the beach; usually it appears much later, about an hour before low tide. In this species display coloration is lost especially

quickly when the crab is held in the hand or bottled, so that in a few minutes it is quite indistinguishable in color from females and non-displaying males.

Non-displaying males: Carapace and all legs olive brown speckled with gold; in addition a set of larger gold spots is invariably arranged as follows: three in a triangle on mesogastric region, one pair on hepatic, one pair on branchial, one unpaired spot on cardiac region. Manus light ochraceous brown. When crab is caught the latter darkens quickly. Chelae bluish-white. Minor cheliped slate gray. Undersides of legs dark slate gray. Sternum and abdomen bluish-white.

Coloration of females and young is exactly similar, except, of course, for the lack of a bright manus in the major cheliped.

Display: Body held moderately high, position unchanged during display. Cheliped starts slowly from position held flexed in front of mouth, sweeps down and outward, almost touching ground, and then on upward at the same slow rate. When it reaches topmost point, without a pause it is brought straight downward and inward swiftly, with a jerk. Entire display is fairly slow, at the rate of about one to a second. Before an interested female the display is considerably quickened, with a higher upward reach, and the small cheliped is vibrated up and down in front of the mouth, three or four times to each gesture of the major cheliped, the crab meanwhile facing the female constantly. Chelae of both chelipeds are held half open. Except for moving to face the female, steps are not usually taken during display.

Shelters: For an account of shelter-building, and its connection with color change and display, see pp. 155-157.

Breeding: Several ovigerous females were seen at La Boca, but none was taken.

Material: A total of 59 specimens was taken from Tenacatita Bay, Mexico; Corinto and San Juan del Sur, Nicaragua; Port Parker and Golfito, Costa Rica; La Boca, Balboa, Canal Zone; and Panama City, R. P.

Uca terpsichores sp. nov.

Text-figs. 4W, 5; Pl. IV, Fig. 19; Pl. V, Fig. 24; Pl. VI, Fig. 31; Pl. VII, Fig. 37.

(See also pp. 149, 150, 153-157, 160, 165, 166, 170).

Diagnosis: Carapace semi-cylindrical in lateral view, front behind eyes slightly more than a fifth maximum width of carapace; orbits scarcely oblique; antero-lateral margins concave, then curving gradually inward and backward; orbital angle very acute, produced. Minor chelae gaping widely throughout length, very slender, tapering, tips articulating poorly, serrations absent. Oblique ridge inside palm of major cheliped present, reaching dorsal profile far out almost at base of dactyl. Strong stridulating ridges, on lower inner proximal part of major manus, and on merus and carpus of first ambulatory of major side, respectively. Eyebrow about as wide as

adjacent portion of eyestalk. Merus of second maxillipeds with hundreds of spoon-tipped hairs, covering inner three-fifths or more of dorsal surface. Abdominal appendage of male slender with rudimentary arm arising at distal. Manus of first major ambulatory with a longitudinal row of thick-set bristly hairs near ventral profile.

Description: Carapace strongly convex, semi-cylindrical in lateral view, widest at orbital angles, regions poorly indicated, naked except for a very sparse scattering of microscopic hairs.

Antero-lateral margins concave, two-thirds width of front behind eyes. They then curve inward and backward very gradually in the form of the usual concave ridge as far as middle of cardiac region. Sides of carapace with a strong median indentation. Front behind posterior margins of eyestalks slightly more than a fifth maximum width of carapace, the distal part of its marginal ridge obsolete. Orbital angle very acute, produced. Upper margin of orbit sinuous, scarcely oblique. Eyebrow about as wide as adjacent portion of eyestalk, moderately inclined, traceable outward almost to orbital angle. Lower orbital margin projecting strongly, even beyond level of front, with strong crenulations only externally, those on inner half being almost or completely obsolete. Suborbital region completely naked. Pterygostomial region tumid. Third to sixth abdominal segments in male almost completely fused.

Spoon-tipped hairs on merus of second maxilliped abundant, arranged in about 25 to 30 rows, covering inner three-fifths or more of dorsal surface, and numbering roughly about 125 to 200, counting only those spoon-tipped hairs which are long enough to project beyond inner edge of merus. Ischium of third maxilliped strongly convex, practically naked, its median groove absent and inner groove obsolescent.

Minor chelae very slender, almost twice as long as palm, gaping widely throughout to the corneous, tapering, poorly articulating tips. Prehensile edges without serrations, but with a few long hairs in median portion. Oblique row of hairs along inner sides of dactyl and pollex represented by a few long isolated hairs and well developed terminal brushes. Traces of other rows outside, and along dorsal and ventral profiles; short external terminal brushes.

Large cheliped of male with arm and wrist externally finely granulate on rugosities. Hand about four-fifths as broad as long. Upper surface of palm rounded, bent over proximally to bound carpal cavity sharply; lower margin moderately cristate. Entire upper and outer surface covered with fine granules, larger dorsally. On inner lower proximal side of palm is a well developed stridulating ridge, composed of short elevated lines, roughly parallel to each other and to the longitudinal axis of the cheliped; carpus of first ambulatory on major side with a row of tubercles opposable to the stridulating ridge; tubercles continuing in an oblique row on distal end of ambulatory merus.

An oblique tuberculated ridge on inner side of manus of major cheliped, starting from lower margin near base of pollex, continuing to carpal cavity, and then curving upward and forward to reach the bent over dorsal margin almost at the base of the dactyl. Although composed of a single row of tubercles throughout most of its length, in its terminal portion it merges with a cluster of tubercles. Carpal eminence moderately developed. A short curving row of tubercles arises close to dorsal margin at base of dactyl, and continues, after an interruption, for a short distance out along pollex close to prehensile margin. Across base of dactyl, distal to this first row, is a row of small, rudimentary tubercles.

Major dactyl slender, about once and a half times as long as manus, finely granulate basally and along dorsal profile, curving gradually downward beyond tip of pollex. The latter is also slender, the tip tapering and curving slightly upward. Gape wide throughout with numerous small teeth, of which one near base of dactyl and about four scattered along pollex are enlarged. Those on distal two-fifths of dactyl are remarkably fine and even, and are serrations rather than teeth. Traces of rows of tubercles near prehensile edges of both dactyl and pollex, both externally and internally.

Ambulatories slender, the merus scarcely enlarged. Manus of first ambulatory on major side short and thick, with a row of thickset bristly hairs near ventral profile.

Abdominal appendage of male slender, the short arm arising about four-fifths of distance to tip.

Measurements: Male holotype, length 6.3 mm., breadth 10.4 mm., base of manus to tip of pollex 16 mm.; 2 female paratypes, length 6.4 mm., breadth 11 mm.; 1 female paratype, length 6.2 mm., breadth 10.5 mm.; 1 male paratype, length 6 mm.; 7 males 3.7 to 5.8 mm.; 5 females, 3.7 to 5.7 mm.

Color: Displaying males observed through binoculars: sometimes completely pure white, except for lower outer part of manus, base of pollex and inner side of merus, which are bright shell pink to violet pink. More often there are markings of yellow ochre on carapace, in addition to, or instead of, yellow ochre on the upper part of the merus of the major cheliped, outside and in. The anterior side of the ambulatory meri are apparently always white.

Females plain grayish, not spotted.

Display: Body held high off ground, legs stretched, during an entire series of displays. Cheliped starts from position extended straight forward in front of crab, touching or nearly touching ground. It is then elevated, diagonally upward, with a slight outward curve, then dropped with a jerk into its original place stretched in front of crab. A pause follows, so that the accent is here. The small cheliped makes a feeble corresponding gesture. A few steps may be taken during display in either direction. Movement is swift, about two displays

taking place to the second. When at the mouth of the shelter, before an interested female, the cheliped may be extended stiffly straight out at side, either held motionless or vibrated up and down with extreme rapidity; meanwhile, at random one ambulatory or another, and sometimes the minor cheliped as well, are raised and extended laterally, then returned to place and another leg at once extended; sometimes a leg on each side—seldom members of the same pair—are in the air at a given instant. The crab does not move at all from its chosen display spot, and the effect is that of a complicated dance step similar to a clog.

Shelter: In this species the shelters erected by displaying males are similar to those of *U. latimanus*, but form more perfect hoods, and are far superior to those of *U. beebei*. The shelters are the largest of all three species, measuring up to 30 mm. high, 20 mm. wide (more than twice diameter of the hole), up to 5 mm. thick, and always forming a complete hood overhanging the entire mouth. Relative to the size of this diminutive crab, which is at most about 6.5 mm. long, the size of the shelters is even more remarkable. In general, about one-third of the displaying males of this relatively rare species built shelters every day at La Boca during February, although at the end of that month and in the first two days in March—when observations ended—the proportion was larger; hence it is likely that this species had not yet attained the full breeding season. No ovigerous females were seen. The method of digging is in general the same as in the other two species (see p. 157).

Burrow: Six to eight inches deep; almost straight, with a slight turning at the end.

Growth: In the smallest males in the collection, 3.7 mm. long, the stridulating ridge is already well developed.

Affinities: *O. terpsichores* is closely related to *musica*, a northern form, which almost certainly has developed directly from it. The two species are, however, perfectly distinct. In *terpsichores* the carapace—especially the branchial, buccal and pterygostomial regions—are much less swollen than in *musica*; the gape between the chelae of both major and minor chelipeds is less; the arm of the abdominal appendage in the male is scarcely more than rudimentary, instead of well developed; the front is somewhat deeper and the sides of the front less divergent, so that it appears distinctly narrower, although there is little actual difference; the distinct parallel lines (not counting those which merge with the margin) forming the stridulating ridge on the major manus are fewer in number (between 8 and 12) instead of between 14 and 16; finally, adult male *terpsichores* measure at most 6.5 mm. in length, instead of 8 mm. as in *musica*, the crab as a whole being about two-thirds as large. These differences are also true of immature specimens of both species.

Females are easily distinguished from those of *latimanus* by the obsolescence of the anterior marginal line of the front; by the more swollen carapace with the antero-lateral margins longer,

more concave, and slanting more sharply outward; by the eyebrows, which are much less inclined; and by the strongly projecting lower orbital margins. They may be told at once from those of *deichmanni*, *limicola* and *crenulata* by the breadth of the eyebrow. A useful characteristic is the meeting of the dorsal end of the oblique ridge inside the major palm with the ridge at the base of dactyl, distinguishing males of both *musica* and *terpsichores* from all other species in Group 5.

Range: From Corinto, Nicaragua, to Old Panama, R. P.

Local Distribution: Found on protected shores of muddy sand near the mouths of streams.

Material: The 17 specimens taken consist of the male holotype, Cat. No. 4144, from La Boca, Balboa, Canal Zone; 1 male and 3 female paratypes, Cat. No. 4145, from the same locality; 1 female, Cat. No. 381,159, from Corinto, Nicaragua; 1 male and 3 females, Cat. No. 381,160, from Port Parker, Costa Rica; 4 males and 1 female, Cat. No. 381,161, from Golfito, C. R.; and 2 males, Cat. No. 4146, from Old Panama, R. P.

This species is named for the Muse who presided over dancing.

Uca panamensis (Stimpson, 1859).

Text-figs. 4X, 5.

(See also pp. 149, 151, 159, 161, 165, 167, 168).

References: *Gelasimus panamensis* Stimpson, 1859, p. 63.

Uca panamensis, Rathbun, 1917, p. 412, pl. 149.

Uca galapagensis, Boone, 1927, lower part of fig. 97.

? *Uca mordax*, Boone, 1929, p. 582, fig. 17b, c. (See *Discussion*, p. 177 of present paper.)

Range: Gulf of Fonseca, El Salvador, to Peru.

Local Distribution: This species, even without allowing for its restricted habitat, is one of the most abundant crabs of the tropical eastern Pacific coast. It is almost always present wherever stones are mingled with sand at the end of a beach, or, rarely, just beyond the beach in shallow tidepools under stones.

Supplementary Specific Characters: Spoon-tipped hairs on merus of second maxilliped moderately numerous, usually between about 65 and 80; all are located on distal half of merus on its inner margin, with a few non-spooned hairs projecting beyond them; and are arranged in about 9 to 11 rows. Woolly hairs moderately numerous. Ischium of third maxilliped with median groove absent, inner groove shallow; entire maxilliped noticeably flattened, with few hairs.

Manus of minor cheliped rounded, almost as broad as long, and two-thirds as thick; chelae only slightly longer than palm, broad and thick, gaping moderately to the corneous tips which articulate well. Prehensile edges without serrations. Entire upper distal end of dactyl and lower of pollex covered with a thick brush of long hairs, which continues backward on both chelae, inside

and out, as the usual oblique rows of relatively scanty hairs.

eyebrow slightly more than half as broad as adjacent portion of eyestalk. Lower orbital margin with sharp crenulations throughout. Suborbital region naked except for scanty hairs immediately behind crenulated margin.

Abdominal appendage thick and blunt, with a well developed arm, arising at the beginning of about its distal seventh and lying close against it.

Measurements: The 113 specimens taken include the following extremes of length: largest male, 13.5 mm.; largest female 14.5 mm.; ovigerous females 7.1 to 10 mm.; smallest male 3.4 mm.; smallest female 3.8 mm.

Color in Life: There is a great deal of variation in color in this species which is definitely associated with the color of the sand and stones in the environment. Crabs living on light sand among pale stones are usually grayish-white or yellowish-buff; crabs surrounded by dark gray volcanic sand and dark stones are brownish, olive yellow, dark green, or dark gray, and are often speckled, marbled, or spotted with brown, buff, maroon, dark green or gray. However, even in the same area there is individual variation: one specimen may be entirely creamy white, while another from under the same stone may be light gray with maroon markings. No reliable sexual differences have been discovered, although the major cheliped of the male in dark-colored crabs is usually lighter than the rest of the body. The only two males seen displaying (see below) were side by side on adjacent rocks, one being white, the other pale gray. The sternum and abdomen in all specimens are generally plain grayish-white. The young vary less than the adults, the usual color being lighter or darker grayish-brown mottled with dark gray.

Display: The display of only two individuals was seen, and this was brief and appeared half-hearted. On February 2, on the shore beyond Bellavista, Panama City, two large males mounted to the tops of stones about two feet apart, within a few moments of each other, and began to display. Major cheliped was extended diagonally upward from flexed position in front of both, then lowered without pausing. During each gesture the body was elevated on all the ambulatories, then lowered. Small cheliped held motionless. The display lasted one second, with a wait of between two and six seconds between displays. The entire performance appeared slow and casual. No steps were taken, nor revolutions made. The two males were not facing, and did not pay to the least attention to each other. Each made perhaps ten displays, then, one after the other, they descended and began feeding. No females were in sight before, during or after display. It is probable that the full display of mid-breeding season will prove to involve more activity and be more complicated.

Breeding: Only three of the 45 females taken were ovigerous. All were taken in March, at Uvita Bay, Costa Rica, and on Gorgona Island, Colombia. The eggs, which measure .27 mm. in

diameter after having been preserved in alcohol, number about 4,000.

Food: The young, and to a lesser extent, the adults, sift organic detritus from the sand at low tide in typical *Uca* fashion. The staple food of all fair-sized specimens, however, is the minute algae found in the form of a fur-like growth on stones at low tide. These are plucked, by the minor cheliped in males and by both alternately in the females, just as they are by *Grapsus* and *Pachygrapsus*. Stomach examinations confirm visual observations: in more than a dozen examined from various localities, the contents consisted entirely of rock algae, except for a few sand grains. The latter could be accounted for entirely by the fact that at every high tide sand is stirred up and washed over the stones, and a certain amount sticks to the algae. Of all the adults seen feeding, not more than one-tenth were seen seeking food in the sand. The strong brushes surrounding the tips of the minor chelae, and the remarkable sturdiness of the latter, are doubtless adaptations to this method of feeding.

Burrows and Behavior: In this species, burrows are rudimentary, the crabs relying rather on overhanging stones for shelter and safety. However, all the young dig very short, straight burrows, up to an inch in length, in the sand close to the edge of a stone. The adults, too, often dig burrows, up to four inches long, against the edges of large stones; the tunnels go obliquely under the rocks and are adapted to the contour of the stony ground; the excavated sand is simply brought up in large lumps and dropped a few inches from the hole, at random. It seems almost certain that they dig a new burrow, if any, with every tide. Where adequate sand for digging is lacking, no burrow is attempted, the crab finding shelter during high water underneath a stone; the flatness of the carapace and underparts must be of aid in this mode of life. The crabs have far less sense of "home" than any of the other species of *Uca* observed, and the range of individuals seems to be little restricted. When startled but not pursued, crabs of all ages, but especially the young, teeter back and forth for a few seconds and then remain absolutely motionless for minutes afterward, apparently relying on their coloration for protection. When actually pursued, even when fairly close to their burrows, the crabs prefer to run rapidly, dodging around stones with agility and, eventually, vanishing underneath a large one. Their behavior in general shows them to be among the most adaptable of the genus.

Material: A total of 113 specimens was taken from the following localities: Gulf of Fonseca, near Potosi River, and Corinto, Nicaragua; Port Parker, Culebra Bay, Piedra Blanca Bay, Ballenas Bay, Uvita Bay and Golfito, Costa Rica; Honda Bay and Panama City, R. P.; Gorgona Island, Colombia, Cat. Nos. 37,701, 37,735, 3861, 3892, 38,119, 38,166, 38,197, 38,345, 38,456, 38,517, 38,706, 38,855, 4149, 38,878.

Specimens were, in addition, observed and examined, but not preserved, at the following localities: Parida Island and Cedro Island, Gulf of Nicoya, Costa Rica; and Panama City, Panama.

The specimen illustrated by Boone, 1927, in the lower half of fig. 97, and designated as *U. galapagensis* should be referred instead to *U. panamensis*. It is from Cocos Island and measures 11.5 mm. in length.

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EXPLANATION OF THE PLATES.

PLATE I.

- Fig. 1. *Uca pygmaea*. Male paratype (381,111), dorsal view. Carapace length 5 mm.
 Fig. 2. *U. zacaec*. Male paratype (381,113), dorsal view. Carapace length 5.5 mm.
 Fig. 3. *U. argillicola*. Male holotype (381,134), dorsal view. Carapace length 7.8 mm.

PLATE II.

- Fig. 4. *U. pygmaea*. Major chela of paratype (381,111), inner view. Carapace length 5 mm. \times 5.1.
 Fig. 5. *U. zacaec*. Major chela of paratype (381,113), inner view. Carapace length 6.6 mm. \times 3.4.
 Fig. 6. *U. argillicola*. Major chela of holotype (381,134), inner view. Carapace length 7.8 mm. \times 4.3.
 Fig. 7. *U. tenuipedis*. Major chela of paratype (381,144), inner view. Carapace length 5 mm. \times 5.3.
 Fig. 8. *U. inaequalis*. Major chela, outer view (381,141). Carapace length 6.2 mm. \times 6.2.
 Fig. 9. Same, inner view. \times 6.1.
 Fig. 10. *U. saltitanta*. Major chela of paratype (4124), outer view. Carapace length 6 mm. \times 4.8.
 Fig. 11. Same, inner view. \times 4.6.

PLATE III.

- Fig. 12. *U. inaequalis*. Male (381,142), dorsal view. Carapace length 6 mm.
 Fig. 13. *U. tenuipedis*. Male paratype (381,144), dorsal view. Carapace length 4.5 mm.
 Fig. 14. *U. saltitanta*. Male paratype (4124), dorsal view. Carapace length 6 mm.

PLATE IV.

- Fig. 15. *U. stenodactyla*. Male (381,147), dorsal view. Carapace length 8 mm.
 Fig. 16. *U. beebei*. Male (4133), dorsal view. Carapace length 6 mm.
 Fig. 17. *U. limicola*. Male paratype (381,153), dorsal view. Carapace length 6.5 mm.
 Fig. 18. *U. deichmanni*. Male (381,157), dorsal view. Carapace length 6 mm.
 Fig. 19. *U. terpsichores*. Male paratype (4145), dorsal view. Carapace length 6 mm.

PLATE V.

- Fig. 20. *U. beebei*. Major chela, inner view (4133). Carapace length 6.5 mm. \times 4.6.
 Fig. 21. *U. stenodactyla*. Major chela, inner view (381,147). Carapace length 8 mm. \times 3.3.
 Fig. 22. *U. limicola*. Major chela of paratype (381,153), inner view. Carapace length 5.5 mm. \times 6.

- Fig. 23. *U. deichmanni*. Major chela, inner view (381,157). Carapace length 6 mm. \times 5.
 Fig. 24. *U. terpsichores*. Major chela of paratype (381,161), inner view. Carapace length 5.8 mm. \times 4.1.

PLATE VI.

Abdominal appendages of adult males in *Uca*. Each photograph represents the distal $\frac{1}{4}$ to $\frac{1}{2}$ of the right appendage, outer lateral view.

- Fig. 25. *U. saltitanta*. \times 15.6.
 Fig. 26. *U. batuenta*. \times 15.6.
 Fig. 27. *U. beebei*. \times 15.6.
 Fig. 28. *U. stenodactyla*. \times 15.6.
 Fig. 29. *U. limicola*. \times 25.4.
 Fig. 30. *U. deichmanni*. \times 25.4.
 Fig. 31. *U. terpsichores*. \times 29.
 Fig. 32. *U. musica*. \times 29.
 Fig. 33. *U. latimanus*. \times 29.

PLATE VII.

- Fig. 34. *U. umbratila*. Major chela of immature paratype (4118), inner view. Carapace length 12 mm. \times 1.3.
 Fig. 35. *U. brevifrons*. Third maxilliped of adult male, outer view. \times 6.5.
 Fig. 36. *U. latimanus*. Third maxilliped of adult male, outer view. \times 10.4.
 Fig. 37. *U. terpsichores*. Adult male, in partial display coloration, beside shelter. When color change is complete, the carapace is pure white. \times ca. $1\frac{1}{2}$.

PLATE VIII.

- Fig. 38. *U. latimanus*. Adult male, in dark phase, feeding shortly after high tide. The small cheliped is depositing on the ground a pellet of muddy sand which it has snipped off the posterior part of the buccal frame, after the mouthparts have removed organic matter. Each pellet is formed of half a dozen or more pinches of sand scooped up in rapid succession by the hollowed tips of the same chelae. Similar pellets surround the crab. \times $1\frac{1}{2}$.
 Fig. 39. Same, building shelter.
 Fig. 40. Same, in white phase, displaying beside shelter.

PLATE IX.

- Fig. 41. *U. stenodactyla*. Two adult males, in display coloration, displaying before an adult female (lower right). The third male (with cheliped folded, facing away from female) is *U. beebei*.
 Fig. 42. *U. stenodactyla*, mating. This photograph was taken about ten minutes after Fig. 41, and shows the nearest male in that picture copulating with the same female, at the mouth of her hole.



FIG. 1.

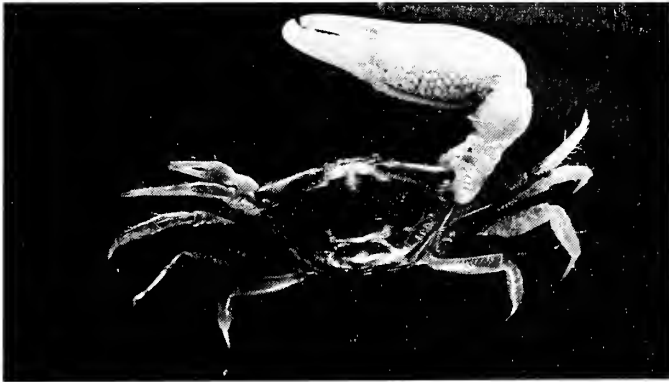


FIG. 2.



FIG. 3.

CRABS OF THE GENUS *UCA* FROM THE WEST COAST
OF CENTRAL AMERICA.



FIG. 4.

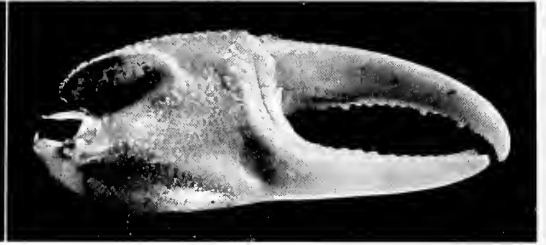


FIG. 5.

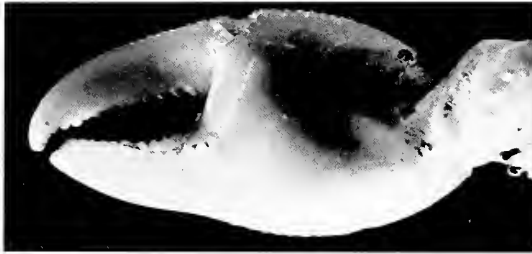


FIG. 6.

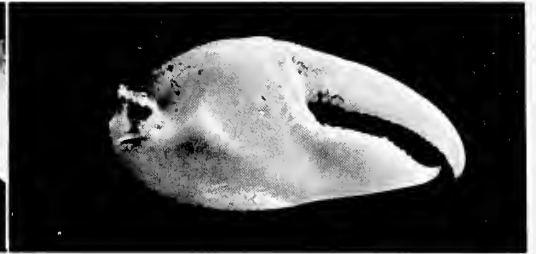


FIG. 7.

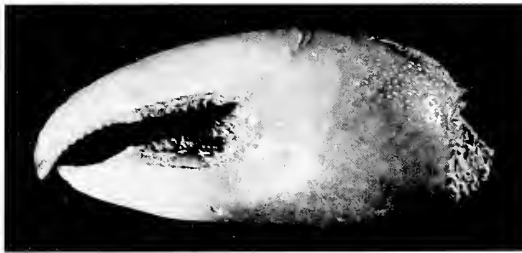


FIG. 8.



FIG. 9.

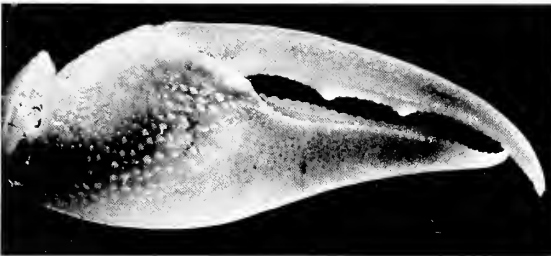


FIG. 10



FIG. 11.

CRABS OF THE GENUS *UCA* FROM THE WEST COAST OF CENTRAL AMERICA.

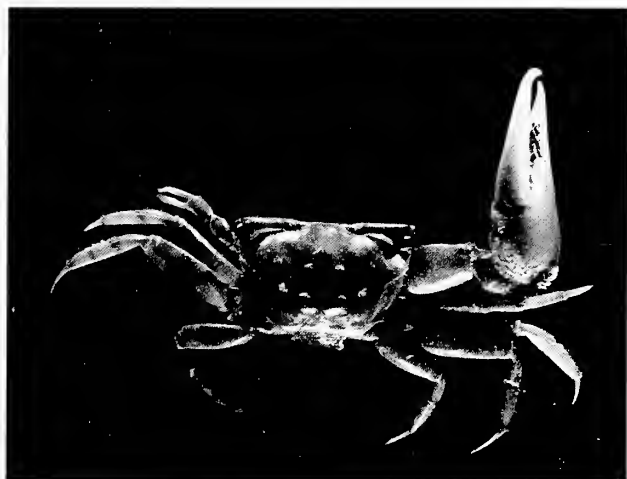


FIG. 12.

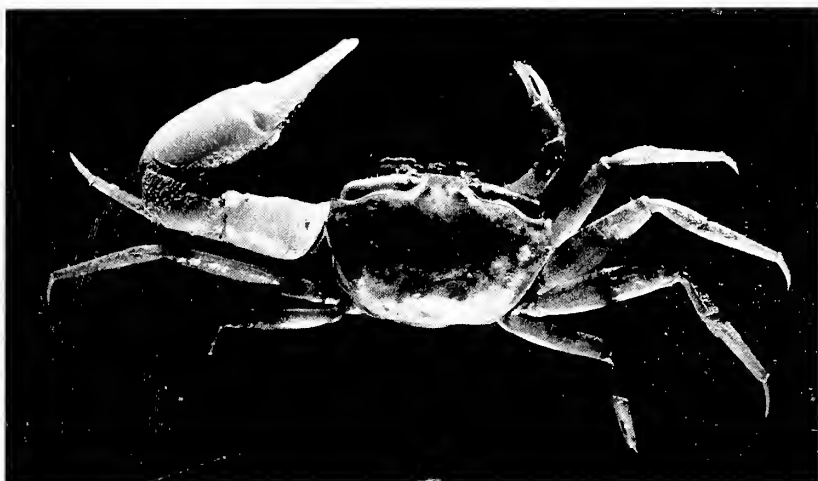


FIG. 13.

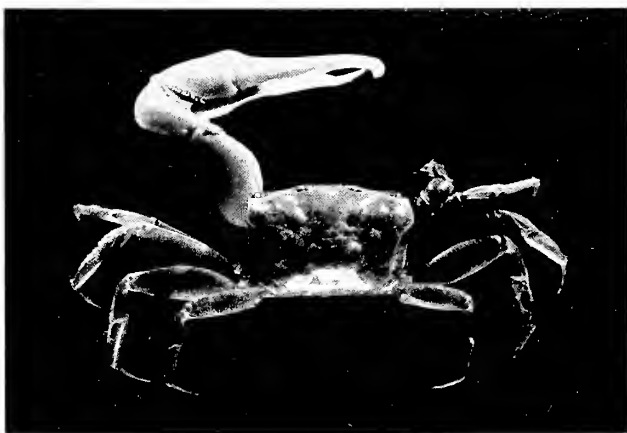


FIG. 14.

CRABS OF THE GENUS *UCA* FROM THE WEST COAST
OF CENTRAL AMERICA.



FIG. 15.



FIG. 16.

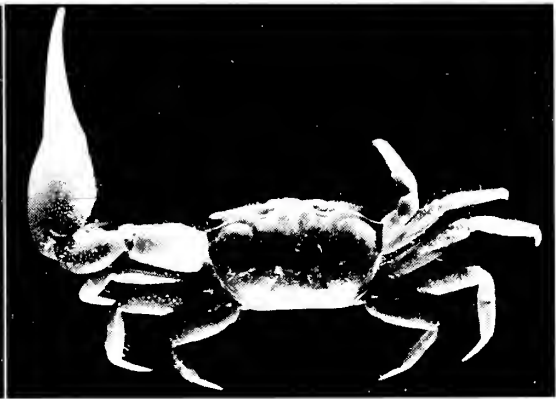


FIG. 17.

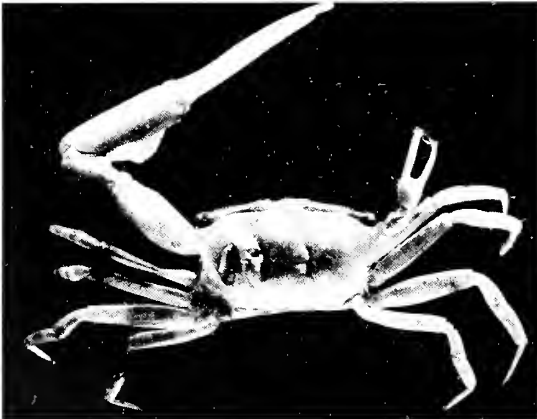


FIG. 18.

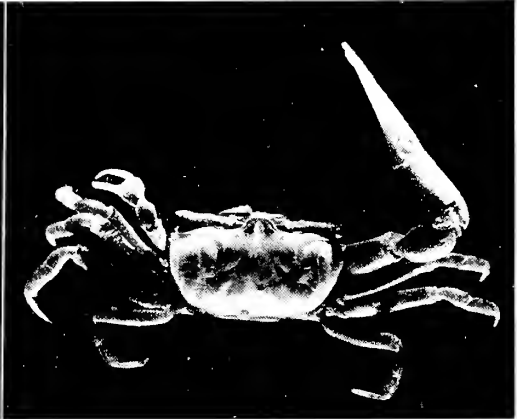


FIG. 19.

CRABS OF THE GENUS *UCA* FROM THE WEST COAST OF CENTRAL AMERICA.



FIG. 20.

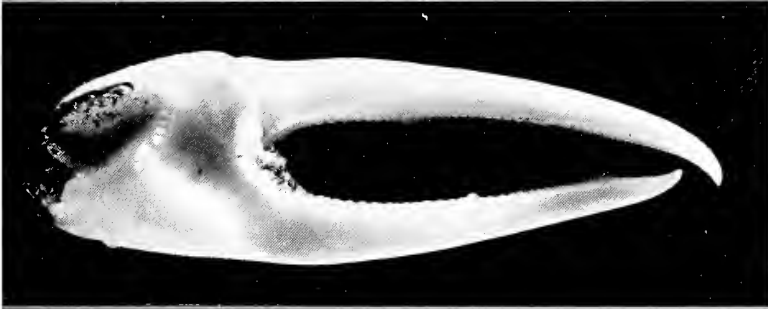


FIG. 21.

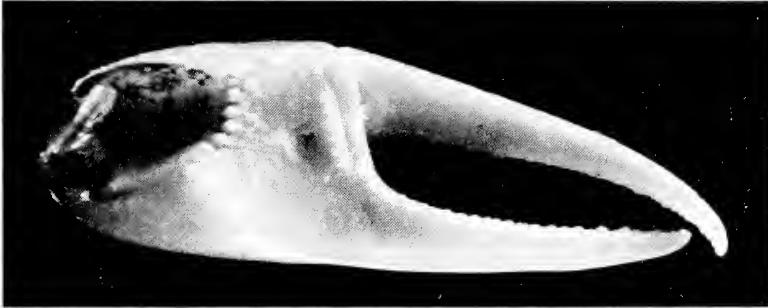


FIG. 22.

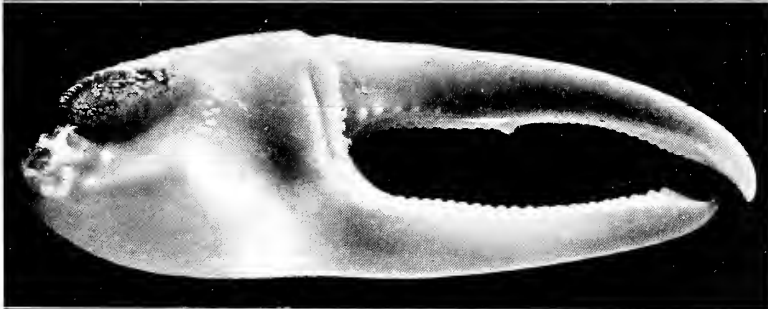


FIG. 23.

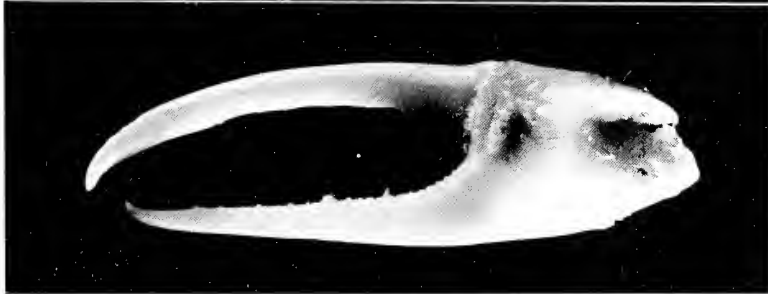


FIG. 24.

CRABS OF THE GENUS *UCA* FROM THE WEST COAST OF CENTRAL AMERICA.



FIG. 25.



FIG. 26.



FIG. 27.



FIG. 28.



FIG. 29.



FIG. 30.



FIG. 31.



FIG. 32.



FIG. 33.

CRABS OF THE GENUS *UCA* FROM THE WEST COAST
OF CENTRAL AMERICA.

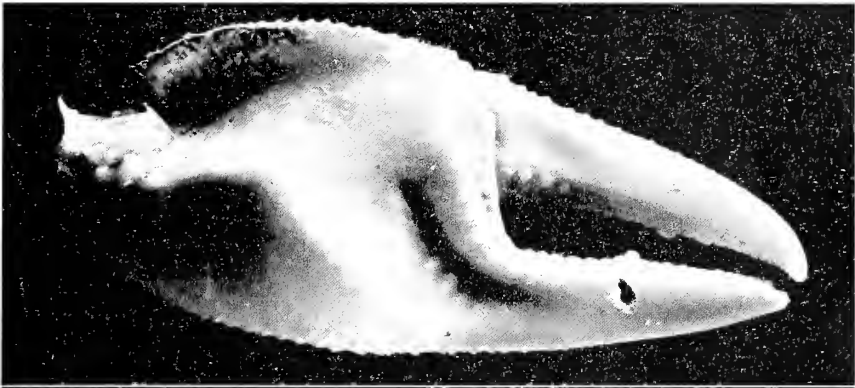


FIG. 34.



FIG. 35.



FIG. 36.

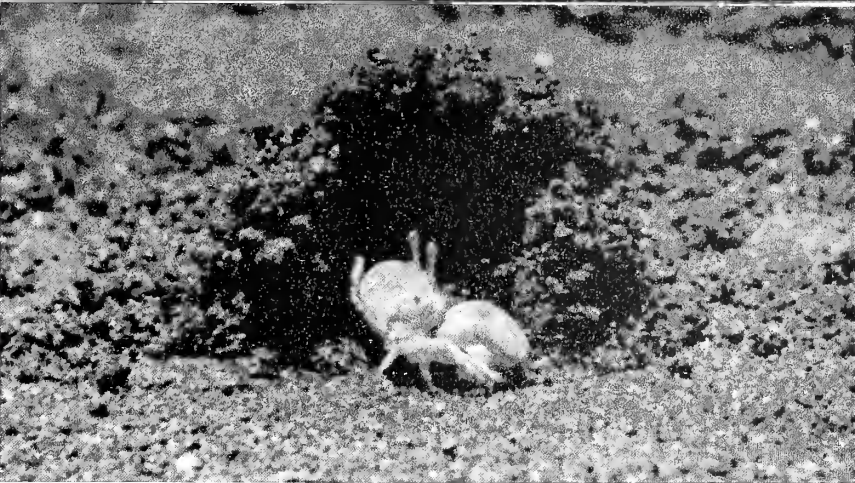


FIG. 37.

CRABS OF THE GENUS *UCA* FROM THE WEST COAST
OF CENTRAL AMERICA



FIG. 38.



FIG. 39.

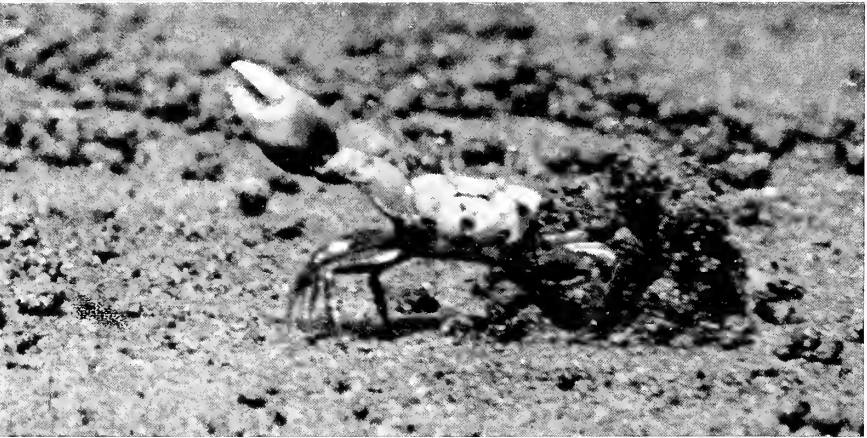


FIG. 40.

CRABS OF THE GENUS *UCA* FROM THE WEST COAST
OF CENTRAL AMERICA.

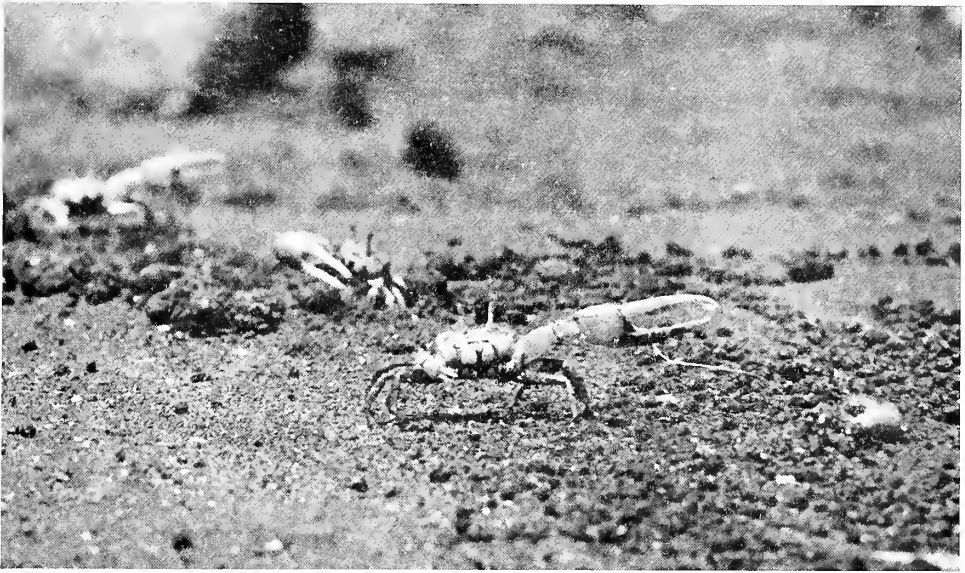


FIG. 41.

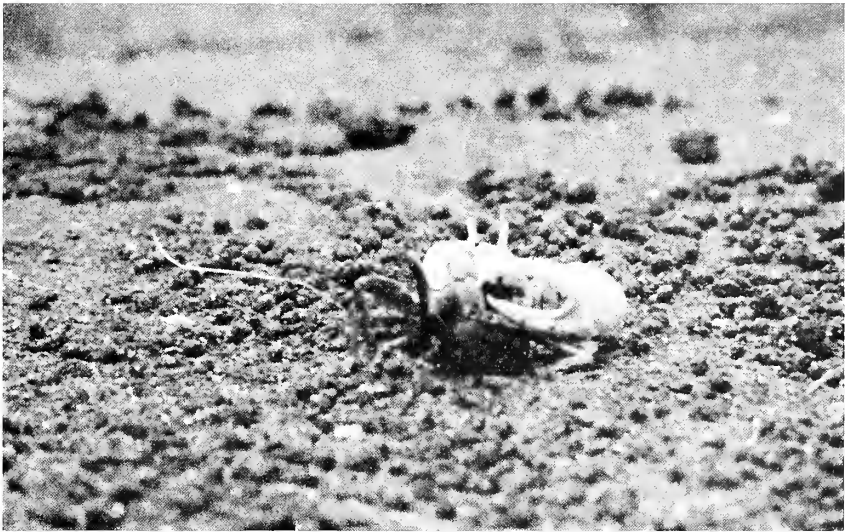


FIG. 42.

CRABS OF THE GENUS *UCA* FROM THE WEST COAST
OF CENTRAL AMERICA.

20.

Eastern Pacific Expeditions of the New York Zoological Society. XXVII.

A Study of Young Sailfish (*Istiophorus*).¹

WILLIAM BEEBE

*Director, Department of Tropical Research,
New York Zoological Society.*

Plates I-V; Text-figures 1-9.

[This is the twenty-seventh of a series of papers dealing with the collections of the Eastern Pacific Expeditions of the New York Zoological Society made under the direction of William Beebe. The present paper is concerned with specimens taken on the Eastern Pacific *Zaca* Expedition (1937-1938). For data on localities, dates, etc., refer to *Zoologica*, Vol. XXIII, No. 14, pp. 287-298.]

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INTRODUCTION.

When the *Zaca* was drifting one night off the western coast of Mexico, a young Pacific sailfish (*Istiophorus greyi*), only three and one-quarter inches in standard length, came to our submerged light and was caught. This was on November 23, 1937. Nine weeks later and twelve hundred miles to the southeast, off Costa Rica, a second specimen, one and five-eighths inches long, was taken under similar circumstances. For comparison with these I have a thorough description of a newly caught adult fish, nine feet, eight inches in length, taken by us off Costa Rica, together with its skull and part of its skeleton. For all these Pacific sailfish I have to thank Mr. Templeton Crocker, for it was under his aegis and on his yacht that the Thirty-eighth Expedition of the Department of Tropical Research of the Zoological Society was made.

For additional study, Mr. Duncan Holmes has kindly sent me a Florida specimen of the Atlantic sailfish (*Istiophorus americanus*) two and three-quarters inches long, and the American Museum of Natural History has loaned me a skull and

nearly complete skeleton of an adult also taken in Florida waters.

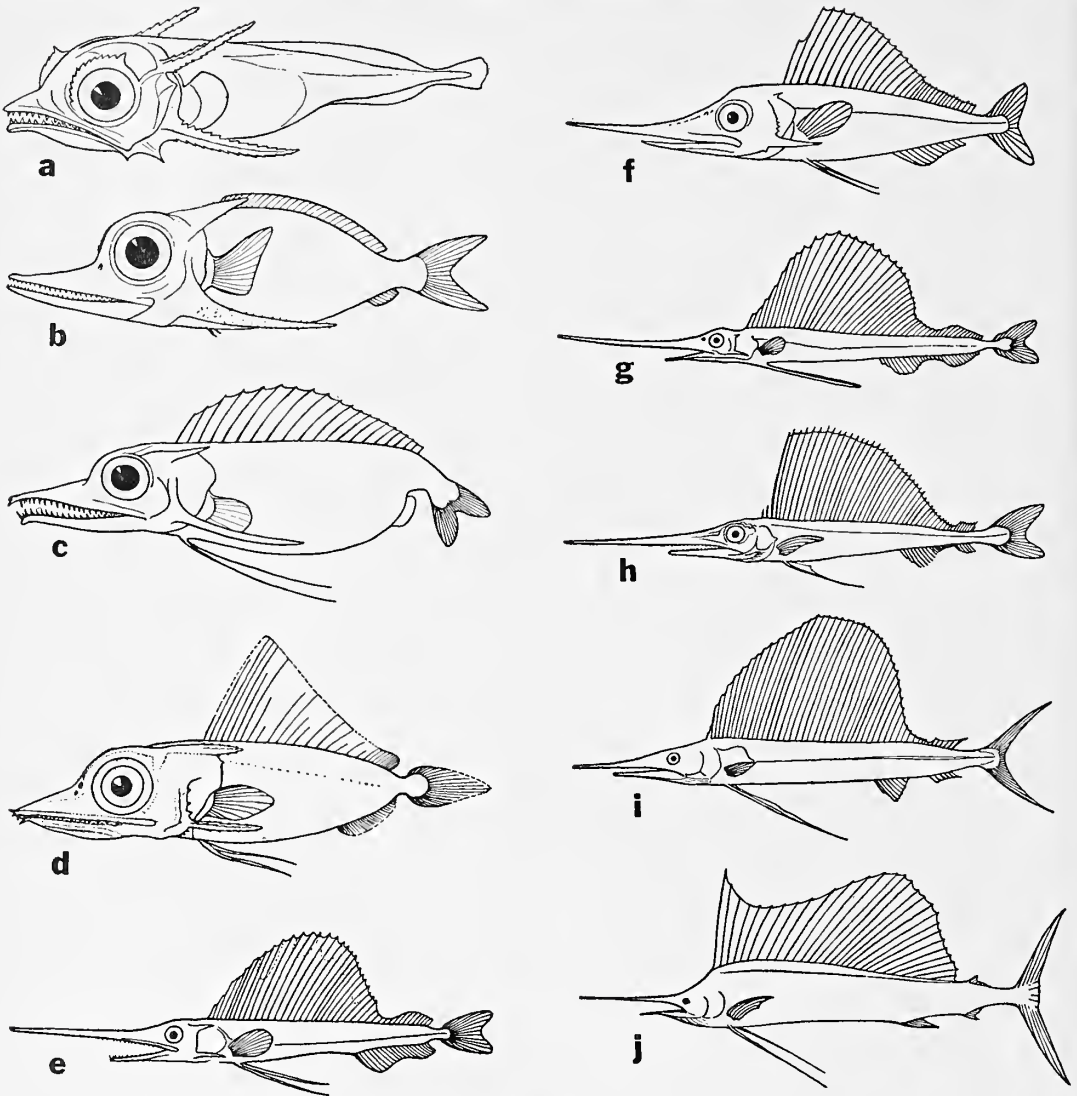
With such meagre material, the direct recording of descriptive facts is all that can be done with any assurance of ultimate value. No attempt has been made at this time to unravel the systematic tangle of the so-called species of *Istiophorus*. Some of the forms have been based on mounted specimens and even photographs, or on a single individual. For purposes of convenience, I use the two commonly accepted specific names for the sailfish of our Atlantic and of our Pacific coasts, *americanus* and *greyi* respectively.

The comparative characters I have been able to examine in my few fresh specimens show confusing variations, and relationship with other characters of doubtful value for differentiation. For example, in two adult skulls, one *greyi*, the other *americanus*, the relative lengths of the projecting part of the upper jaw are 50 percent. and 48 percent. respectively, while the supposed diagnostic characteristic of slenderness of the snout is identical in both.

The extreme weights of the adult sailfish from the two oceans seem to be a definite but rather unusable character of differentiation. The heaviest recorded Atlantic fish weighed 120 pounds, while Pacific individuals certainly reach 190, and very probably 220 pounds.

In the year 1831 Cuvier & Valenciennes described and figured a sailfish, calling it *Histiophorus pulchellus*, which they said was "*n'est long que de quatre pouces*" (Text-fig. 1 h). Ten years later Ruppell described and also figured what he called *H. immaculatus* from the Red Sea, measuring eighteen inches or about 457 mm. (Text-fig. 1 i). Günther in 1873-74 published figures of the first really young sailfish, specimens of 9, 14 and 60 mm. (Text-figs. 1 b, c and f). In 1880 Lütken described a series from 5.5 to 21 mm. and figured the smallest (Text-fig. 1 a). The

¹ Contribution No. 629, Department of Tropical Research, New York Zoological Society.



Text-figure 1.

Nine Stages of Growth of *Istiophorus* (see page 225). **a**, 5.5 mm. (Lütken, 1880); **b**, 9 mm. (Günther, 1873-74); **c**, 14 mm. (Günther, 1873-74); **d**, 16.5 mm. (LaMonte & Marcy, 1941); **e**, 42 mm. (Beebe, p. 210); **f**, 60 mm. (Günther, 1873-74); **g**, 84 mm. (Beebe, p. 213); **h**, 108 mm. (Cuvier, 1831); **i**, 457 mm. (Ruppell, 1841); **j**, 2616 mm. (Beebe, p. 221).

descriptions and illustrations of these small fish were exceedingly sketchy, so I have chosen only to present a few dominant features, which may be of ultimate use in clarifying their age and exact identification, when we have sufficient material for comparison. (Page 225.)

While there are doubtless a number of young sailfish in collections, as yet unrecognized, I know of only three which will soon be reported upon. One of 14.3 mm. in the American Museum of Natural History is being described by Miss Francesca LaMonte (Text-fig. 1 d) and two Pacific sailfish "four and three-quarter inches in

length," taken during the present year by a Field Museum expedition in Panama Bay.

For the staining and clearing of the two young sailfishes of 70 and 84 mm. I am indebted to Miss Gloria Hollister, and for the text-figures to Mr. Donald Greame-Kelly. The photographs were taken by Miss Jocelyn Crane and Mr. Toshio Asaeda. Measurements are from fresh specimens.

Istiophorus greyi Jordan & Hill.

Pacific Sailfish.

Material Studied: One young specimen, of 42

mm. standard length, taken in hand-net at night light, at surface, over 67 fathoms, at 11:30 P. M. March 1, 1938, from the deck of the *Zaca*; on the Eastern Pacific *Zaca* Expedition of 1937-38, of the Department of Tropical Research, New York Zoological Society; Station 215, L-1; 9° 03' North Lat., 84° 06' West Long., 23 miles west of Uvita Point, Costa Rica. Cat. No. 28,426; Col. Pl. Z-201; Photograph 9031.

Field Characters: A small, slender fish, head and snout longer than the rest of the body; eye very large; two prominent cephalic spines, upper jaw projects beyond lower more than the length of the latter; shining steel blue except for white forward belly and lower jaw; tall, circular dorsal fin dusky, with large, black, basal spots and terminal yellow ones; pelvics long, slender, yellow; all other fins, including low, posterior part of dorsal, hyaline. Although one-sixtieth the length of a full-grown fish, this young specimen has all the general aspects of an adult; the enormous dorsal fin, the elongated upper jaw and pelvic fins identify it at a glance. (Plate I, figs. 1, 2.)

Ecology and Habits: There is little enough I can contribute under this heading. This is the smallest Pacific sailfish ever seen or captured. It came to the night light of the *Zaca* as she drifted slowly along on a quiet sea, twenty-three miles off shore, off Uvita Point, Costa Rica, over a depth of about sixty-seven fathoms. Around the light were the usual lot of small fish, scombroids, squirrelfish, demoiselles, puffers, dolphins and brilliantly colored butterflyfish. All were young, and as usual it was always surprising to find such small fry in such deep water, so far out at sea.

The baby sailfish we are studying, one and five-eighths inches in length, was seen as it appeared and vanished several times, but not until it was actually in the net was it recognized. This was about 11:30 P. M. just before we put out the light. When in the water, there was no hint of diagnostic dorsals or pelvics, nor even of beak. In a small aquarium it dashed about with such violence that I feared serious injury to its sail or beak and killed it, my artist getting the exact colors before it expired. Measurements and full color description were also taken. While I watched it darting about, the dorsal was about one-third exposed, but quiescent, and the pelvics were likewise almost hidden. I noticed only quick twists of the posterior body and caudal fin as motive and directional power.

Color: Body shining steel-blue with a small, pale spot on the top of the head, and six, wide, fairly distinct bands down the sides. These vanished soon after death. Upper jaw all steel blue, also sides of head and anterior and upper part of opercles. Eye silvery, bluish-white. Lower jaw dead white, branchiostegals and belly silvery-white. Lower side of body from well in front of anal backward, almost as dark blue as the back. Posterior dorsal, anal and pectorals hyaline; caudal translucent white.

Dorsal in general appearance black with

narrow, lemon-yellow streaks extending up the rays and along the distal edge. In detail, we find three, large, jet-black, slightly elongate, but almost round spots along the central three-fifths of the basal area of the fin, their lower contour partly sunk into the dorsal profile of the body. Entire fin elsewhere with black webs and lemon-yellow rays. Near the edge of the fin, the yellow extends on to two adjoining webs, resulting in five, definite yellow spots. Narrow base of posterior pigmented rays clear lemon-yellow.

From the thirty-eighth back, the remaining elements are hyaline. These are at first short, and then the fin expands into a terminal, higher lobe. The webs of the pelvics are bright straw yellow, the brightest color on the fish. The caudal fin shows a scattering of small but definite round, dark spots, adumbrating the two black areas in the larger specimen.

Measurements and Counts: Total length 46.5 mm.; standard length 42; depth at pectoral 4.2; depth at origin of dorsal 4.2; depth at origin of anal 2.8; depth at peduncle 1.3; head 21.7; eyeball 2.8; iris horizontal 2.3; iris vertical 2; snout 15; snout to dorsal 21; snout to pectorals 22; snout to pelvics 22.2; maxillary 18; lower jaw 8; lower jaw-tip to snout-tip 9.5; front eye to rear opercle 6.7; upper pterotic spine 1.7; lower preopercular spine 2.8; dorsal height, first spine .8; dorsal height, fourth spine 4.3; dorsal height fifteenth spine 13.5; first anal lobe base 1.5; lobe height 2.1; second anal lobe base 1; lobe height 1; caudal fin spread 3.3; central caudal rays 4; caudal lobe 4.7; pectoral base 1; pectoral width 1.7; pectoral length first spine 4.3; pectoral length, fifteenth ray .8; pelvic spine 1.5; pelvic elongate ray 11; pelvic short ray 2.3 mm.

Counts: Dorsal $4 + 36 + 6 + 9 = 55$; anal count $3 + 8 + 7 + 8 = 26$; pectoral count $1 + 18 = 19$; pelvic count $1 + 2 = 3$.

Weight: One-half gram.

General Body Form: This young sailfish is elongate and slender, deepest at the posterior edge of the opercle; anteriorly from the crown, the profile slopes rather gently down and in a long curve to the elongated upper jaw, the elongate portion being curved slightly upward. The body is straight, the slight narrowing caudally being brought about by a gentle slope down of the dorsal profile. The depth is contained in the standard length exactly ten times. Between the end of the unpaired fins and the origin of the caudal the peduncle is distinctly narrowed, the terminal portion of the body widening again to accommodate the caudal.

Head: The bones in general seem well developed, but the frontals and supraoccipital are so thin that every detail of the brain is visible.

Skin: The body is covered thickly with minute erect spines, becoming more dense on the posterior half of the body so that the separation of the spines is about equal to their height. They are greatly reduced or absent on the head, and the skin near the bases of the unpaired fins and their sheaths are also spineless. Details of the scales

are not apparent in the uncleared specimen. As in the adult fish, the dorsal and pelvic fins are furnished with deep subdermal sheaths into which they can be folded and sunk out of sight for stream-lining.

Snout: The snout, even at this early stage, is characteristic, projecting far forward, beyond the lower jaw. It is formed by an extension of the premaxillary, and in this young individual this structure is almost a full third of the length of the fish. The snout is curved gently upward and slightly flattened, the depth and width half-way to the tip, being .62 and .86 mm. respectively. Two deep lateral furrows mark the dorsal surface.

Eye: The eyes are very large, occupying much of the side of the head, breaking the dorsal contour, as well as the line of the upper jaw, behind the posterior extension of the maxillary. The eyeball is not quite round and in the iris this dorso-ventral flattening is still more apparent. The interorbital space is flat, but marked by several furrows.

Nostrils: These are relatively large, being one-fourth the diameter of the eye, and they are close in front of the eyes. They are divided by a broad, vertical band into two openings. The partition flares out and forward, and is continued around the anterior opening, giving it a low, tubular appearance, while the frame of the posterior opening is flush with the side of the head.

Opercles: Large but not strongly ossified at this age. A transparent bony ridge arises in front of the eye, just above the nostril, passes back in an even curve over the eye, and terminates in a long, two-keeled, serrated spine, 1.7 mm. in length. A second, larger spine springs from the lower angle of the preopercular, 2.8 mm. long. This reaches back beyond the origin of the pectoral. Both spines are directed slightly outward at a marked angle from the body plane.

Two small, short, toothed ridges arise from the posterior part of the posttemporal and the upper end of the supracleithrum.

Mouth: If we disregard the specialized extension of the premaxillary into a prolonged snout or sword-shaped beak, the mouth of this young sailfish presents no unusual features. The posterior end of the maxillary is at the vertical of the posterior rim of the iris. The mandible is stout and short, contained in the upper jaw two and one-quarter times. It terminates two eye diameters in front of the eye itself, so that this is the only effective, prehensile part of the mouth.

Teeth: The palatine teeth begin 2.5 mm. in front of the posterior end of the maxillary. They are the same size as those on the maxillary, but in an irregular double row, and placed much closer together. The teeth in the maxillary are widely spaced, extend quite to the tip, and tend to arise in separate clumps. At first these are in twos and threes in linear arrangement. In the distal fourth, however, the groups consist of three to seven teeth, and are irregularly arranged, sometimes reaching almost to the center line of

the beak. At the very tip are several larger, isolated teeth, one or two in the central line, barracuda-like. There are two, terminal, hyaline, serrated spines, which flare obliquely outward from the very tip.

The mandibular teeth are in two rows, the outer irregular and small. The inner ones are larger, almost palisade-like, often in a double line. These increase in size and inward curvature toward the tip of the jaw, until the last twenty are relatively large fangs, the tips of those on opposite sides almost touching as the jaw becomes narrowed. At the tip, several fangs are directed obliquely forward, forming a pincer-like arrangement, the upper ones curving downward, and the lower ones upward. The mandibular teeth fit between those of the palatine and maxillary.

Dorsal Fin: The dorsal fin is continuous and consists of 55 elements. When the anterior 38 spines are elevated at right angles to the body, the fin forms an almost perfect half circle. Although the whole fin is connected by webs, it may be divided into four more or less distinct parts. The first four spines are closer together and relatively shorter than the succeeding ones. In the adult these seem to be affected as a unit, although in one of several different ways. The first three may disappear altogether above the skin, or they may lose the connecting webbing. In the present specimen, Number 1 is only just visible (.16 mm. in length). The difference in length between the fourth and fifth elements is more than twice as great as between any preceding or succeeding elements.

The next part includes 36 ray-like spines representing those which remain in the adult and form the typical sail. The succeeding division in turn is not radically marked but can be distinguished, forming a group of six elements which are very short and of equal length. They form the area which in the full-grown fish either disappears altogether, thus resulting in two separate dorsal fins, or anteriorly persists as a few stunted elements. It is the disappearance of this group which reduces the dorsal count in the adult so considerably. The last nine elements are rays, judged by the complex splitting of their tips and the presence of cross nodes. They are small but are very even in length.

Anal: The anal fin, like the dorsal, is continuous at this stage of growth, and contains 26 elements. The future changes are fairly well adumbrated even in the outline of the present fin, two well-marked lobes, anterior and posterior, being connected by a deep curve of short elements. The first three are spines, quite different from the remainder which are obviously rays. The first 11 elements will form the first anal in the adult, while the succeeding 7 will usually disappear, leaving the last 8 for the ultimate second anal. The central third are not only shorter than the others but much more fragile, breaking easily at the ray joints. The posterior third is solid, close together, and already corre-

sponds to that part of the dorsal immediately above it. In the adult sailfish the anal will be reduced from 25 or 28, to 16 or 17.

Caudal: There is no hint of the great flukes of the fullgrown sailfish in the undistinguished tail fin of this baby. The lower lobe is slightly longer than the upper, but the spread is considerably less than this length. The lobes are rounded and very slightly indented in the mid-line.

Pectorals: The pectoral fin is well developed, rather short-based, of 18 or 19 elements, the first of which is a very broad and flat spine. The rays are graduated in a very oblique but straight line along the posterior edge, from the 1st which is 4.3 mm. in length, down to the .8 of a mm. of the 15th ray. The general shape of the fin is triangular, with no hint of the falcate curve of the same organ in the adult fish.

Pelvic: These fins are already almost as specialized in reduction of elements and in elongation of a single ray as they are in the adult. In the living and recently dead individual under consideration, these fins showed an unexpected breadth of webbing, and this was constantly distended, as shown in the colored plate. The condition of these pelvics is so similar to those of the cleared and slightly larger individual next to be described that consideration of all details is better left to that fish. Although the pelvic skin sheath in this young sailfish is both deep and long, it cannot quite accommodate the attenuated tips, which, when all the rest of the fin is reefed and hidden, must lie exposed along the abdomen. These tips almost reach the anal fin, falling short by only about 1 mm.

Istiophorus greyi Jordan & Hill.

Pacific Sailfish.

Material Studied: One young specimen of 84 mm. standard length, taken in hand-net at night light, at surface, over 600 fathoms, at 11:30 P. M. November 23, 1937, from the deck of the *Zaca*, on the Eastern Pacific *Zaca* Expedition of the Department of Tropical Research of the New York Zoological Society. Station 186, L-1; 17° 38' North Lat., 102° West Long., 23 miles west of Sihuatanejo, Guerrero, Mexico. Cat. No. 27,140; Col. Pl. Z-106; KOH 2331. Photographs 8460 and 8461. (Plate II, figs. 3, 4.)

Field Characters: Similar in general appearance to the slightly smaller, preceding young sailfish, except that the cephalic spines have decreased in size, and the intense blue color has spread over the proximal three-fourths of the dorsal fin, while on the body the blue is restricted to the upper half. The yellow on the dorsal and the pelvics is less intense, and the black spots on the dorsal fin have increased in size and number.

Note: Except for the color and many of the measurements which were made from the fresh specimen, the entire study of this individual is based on its appearance after it had been stained and cleared. The shape and relationship of even the most delicate bones are thus unaffected by dissection or disarticulation.

Ecology: On the night of November 23, 1937, when the *Zaca* was drifting slowly, twenty-three miles off shore from Sihuatanejo, Mexico, the sub-surface light was put overboard at 9 P. M. Fish were scarce, and most were snapped up by marauding squids. Several *Cololabis* appeared, and eight very young *Coryphaena* or dolphins with varied patterns, changing as we scooped them aboard. A three inch *Cubiceps*-like fishlet came in and at 11:30 a small, inconspicuous fish, which barely escaped the squids several times before it was caught. It proved to be the first young Pacific sailfish we or anyone else had ever seen. In standard length it measured three and one-quarter inches, or 84 mm.

Color: Head and back rich cobalt blue above, silvery below, including lower jaw and sides of head up to half eye level; upper jaw blue for two-thirds and black on distal third of its length; six or seven broad light bands down the side of the body; webs of anterior dorsal elements dusky yellow, unmarked; all of the central part of the fin pale blue, becoming lemon yellow toward tips; much of the dorsal is covered with very large black spots, four of which, oval in shape, touch the back; an oblong spot is attached to the upper part of the second lower spot; six large, slightly elongated spots extend along the margin of the fin, separated by the lemon yellow areas, the two posterior rather close together; pelvic fins pale yellow; pectorals, posterior portion of dorsal and anal, and caudal transparent; the pectoral has a large dusky spot near the anterior base, and the caudal has a roundish dark spot in the center of each lobe.

Food: Dr. Wilson reports that there were six copepods in the stomach, one *Corycaeus*, one *Oncocaea* and four *Farranula gibbula*. In addition to these was a small larval fish.

Measurements: Total length 91 mm.; standard length 84; depth at pectoral 6.4; depth at origin of dorsal 6.8; depth at origin of anal 5; depth at peduncle 1.7; head 45; eyeball 4; snout 34.6; snout to dorsal 43.4; snout to pectorals 45.4; snout to pelvics 46; maxillary 38.6; lower jaw 14; lower jaw-tip to snout-tip 25.4; upper pterotic spine 1.4; lower preopercular spine 2.5; dorsal height, second spine .4; dorsal height, fifth spine 5.3; dorsal height, fifteenth spine 27.8; first anal lobe base 2.4; lobe height 3.4; second anal lobe base 2.4; lobe height 1.7; caudal fin spread 10.7; caudal lobe 8.3; caudal middle ray 6.5; pectoral base 1.4; pectoral width 2.5; pectoral length, first spine 6.4; pectoral length, fifteenth ray .3; pelvic spine 2.2; pelvic elongate ray 20; pelvic short ray 2.8 mm.

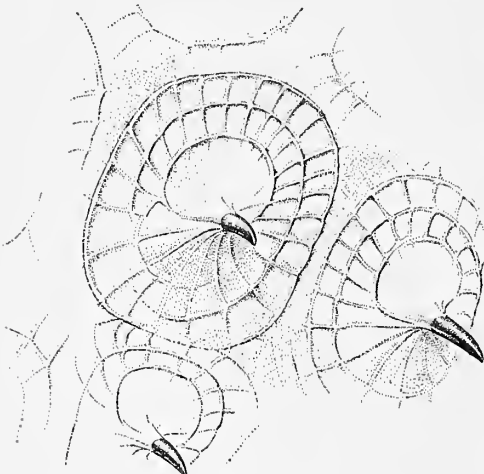
Counts: Dorsal count $(1)4 + 37 + 6 + 8 = 56$; anal count $3 + 6 + 8 + 8 = 25$; caudal count $12 + 8 + 7 + 12 = 39$; pectoral count $1 + 18 = 19$; pelvic count $1 + 2 = 3$.

General Body Form: This is much as in the 42 mm. specimen, but is even more slender, as the depth is contained somewhat more than twelve times in the standard length.

Skin: Staining and clearing reveal unsuspected scalation of remarkable complexity. Scales are

found over the entire body and even a short distance out on the caudal rays. They extend forward on the mid-dorsal line in front of the dorsal fin as far as the vertical of the occiput. Elsewhere on the head they are to be found only in front of the preopercle, a space which they cover completely, and on the area over the post-temporal, from which a very few scattered scales extend down on to the upper part of the opercle. The scales become smaller on the posterior half of the body. The largest observed are near the preopercle, and measure .3 mm. in diameter. (Plate III, fig. 5.)

The density of the scales on the body is such that the edges of the scales touch one another. They may be round, oval, ovate, or almost diamond-shaped, or with slight variations of these outlines, fashioned to fill up most of the interstices between adjoining scales. On the edges of the scaled areas, where there is a slight openness of distribution, the individual scales are usually oval. This separation is especially marked on the posterior half of the peduncle and the remainder of the area affording support for the caudal fin. Here the isolated scales are separated by almost their diameter. (Text-fig. 2.)



Text-figure 2.

Scales of 84 mm. *Istiophorus greyi*. $\times 123$.

A typical scale consists of two outer rings coarsely marked with wide-spaced radiating lines. Inside the second ring is a small clear area, and from the posterior rim of this (posterior to the main axis of the fish) arises a long, slender, sharp spine. Posterior to the spine the rings usually break down, and the radiating lines are continued unbrokenly across the whole area and often project beyond the rim as external spines. Other much more minute spine-like projections may be seen at other external segments of the scale, which seem occasionally to anastomose with corresponding projections from adjoining scales. The average scale measures .2 mm. in diameter. Every scale has one of these spines,

straight or slightly curved. The only exceptions are the scales immediately behind the pectoral fins, which are altogether smooth. This is the area against which the pectorals are applied when pressed close to the body.

Intermuscular Bones: These are visible as elongate needles of pre-bone. They appear in two rows, one sloping obliquely down and back under the scales in the upper fourth of the sides, and the other slanting back and up in the area above the lateral line.

Lateral Line: A mucous canal, marked by a very narrow but continuous bare line between the scales, passes along the upper branch of the posttemporal, over the tip of the supracleithrum, and curves gently upward to the vertical of the 14th dorsal ray. At this point it bends obliquely down and back to the vertical of the 17th ray and on the mid-line of the body. Here the shape changes into a lateral line effect of numerous, diamond-shaped openings between the scales, separated by hour-glass strands of tissue of varying degrees of thickness. There are about 174 of these pores, ending on the peduncle where the succession is lost in the general separation of the individual scales.

Cephalic Ridge and Spines: A bony, finely serrated ridge arises directly above the nostril, curves backward over the eye, and ends in a strong, sharp spine arising from the tip of the pterotic, 1.4 mm. long, with dorsal and ventral edges strongly serrated. At the lower, posterior angle of the preopercular is a larger spine, 2.5 mm. long, also serrated, with the tip slightly out-curved. There are several small, additional spines below the base of this larger one, and two more above it, along the posterior edge of the preopercle. Both of these cephalic spines are relatively and actually smaller than in the 42 mm. specimen. The posttemporal ridge is reduced to three small teeth.

Dorsal Fin: This relatively enormous fin is continuous in this young sailfish, and in the stained and cleared state is seen to possess 56 elements. The first of these is wholly subdermal, and would never be suspected in the uncleared specimen, although it has a perfectly good but minute spine and an equally distinct but unattached base. It is undoubtedly not an incipient element but a relic, in the course of disappearing.

The fin as a whole is separable into four, more or less distinct divisions. Including the anterior subdermal element, the first five have all the characters of real spines, and in addition there is a real spatial demarcation in relative length between the 5th and 6th elements. This is indicated clearly by four measurements:

- 4th— 2.6 mm.
- 5th— 5.4 mm.
- 6th—10.3 mm.
- 7th—12.4 mm.

The succeeding thirty-seven elements have rayed tips but no nodes, so that their status as

spines or rays is equivocal. However, in the adult, the rayed tips disappear, so I shall class them as spines. This is equally true of the succeeding six, but they are set off by abruptly reduced lengths, and represent those which, in the adult fish, will disappear above the skin or remain represented only by stubs. The anterior boundary of these two groups is evident in another comparison of lengths:

- 41st—5 mm.
- 42nd—4.8 mm.
- 43rd—3.1 mm.
- 44th—2.6 mm.

The future vanishing of these six elements will inaugurate the external appearance of two separate dorsal fins. This is adumbrated in this young specimen by the distinctness of the last eight rays—true rays both in distal branching and the presence of nodes. They are almost twice the length of the preceding and are subequal in length among themselves. In addition their bases are twice as close together as any of the other dorsal fin elements.

The longest element in the dorsal is the fifteenth, which measures 27.8 mm. in length.

Anal Fin: This fin has 25 elements. The anterior three are spines and the succeeding fourteen elements are ray-like spines. Intimately associated with the three anterior spines are the succeeding six elements, all webbed together, all of a relatively common length, and with their bases very close together. A similar segregation is even more pronounced in the posterior eight unquestionable rays, which are two and one-half times as long as those which go before, and in their turn arise close together. This posterior anal group is very similar to and placed directly beneath the posterior eight of the dorsal. Connecting the two incipiently separate anal groups are eight short, widely spaced rays. These, like the corresponding dorsal equivalents, are doomed to subsequent disappearance.

Caudal Fin: There are 39 elements in the entire fin, 20 dorsal, and 19 ventral. Counting from the smallest, most anterior, undivided, dorsal raylet or spine-like element, there are 12 succeeding ones increasing rapidly in length. The 12th, however, is closely associated, in sudden elongation and strength of ossification, with the next eight, although all of these latter are true rays and are divided into terminal branches. It is thus included in the closely knitted group which ultimately will metamorphose into the dorsal half of the powerful tail crescent. The same sequence is repeated in the ventral half of the fin, except that there are only 7 divided rays instead of 8.

The two caudal lobes in this young fish are equal, 8.3 mm. in length, while the central rays are half as long, 4 mm. These latter will become still less important in subsequent development, until they come to measure less than one-fourth of the swimming lobes.

Pectoral Fin: The shape is roughly triangular, with no hint of the falcate, adult form. It is broad and well-developed, with a stout spine and eighteen rays, but it must function more for balancing than play any important part in swift swimming, for it is only about one-twelfth of the body length, instead of a sixth as in the adult fish. It is well ossified, however, with sturdy bases, and shows no such specialization as we find in other structures in the make-up of this young sailfish. The formula is 1 + 18.

Pelvic Fin: This 84 mm. sailfish is far too old to give us a hint of the early, more normally developed fin such as would probably be apparent in a fish one-third of an inch long. Here we have a sharp, strong spine, closely attached to the elongate ray, free only at its tip, and measuring 2.2 mm. The elongated ray is 20 mm. and is provided with a web of surprising width and strength, so that this fin is by no means as useless as its attenuated length would suggest.

On the inside of the fin is a second ray, free, freely movable and webbed, with a strong, bony base of its own.

The fact that this pelvic fin, as well as the dorsal, is so well supplied with a deep, adequate sheath, hints that it is not merely an over-specialized remnant of some past functional value, but is today of considerable use in some way unknown to us. The strong fore and aft development of the pelvic girdle also suggests an importance for muscular attachment inconsistent with a vestigial structure.

Skull: The relation of depth to length of the skull in the young sailfish is 7.5 times as compared with 6 in the adult and 7 in *Xiphias*. The chain of suborbitals is very distinct, the components being considerably larger and more united than in those shown by Cuvier in *Xiphias*, but of course far less developed than we find in *Scomber*. They are oblong, but their outer borders are so irregular and they are so diversely connected with each other that an accurate count is impossible. They surround the orbit in somewhat more than a half circle.

General observation of the anterior part of the skull reveals that the sword is dominantly premaxillary, with the chief center of ossification not far from where the maxillary cuts in between the two posterior branches of the anterior element. The nasal is sharply delimited below where it parallels the maxillary, and it forms a considerable part of the antero-superior contour of the narial cavity. Anteriorly it is ossified with the superior branch of the premaxillary, but the line of demarcation can easily be made out. The vomer has a strong anterior facet.

The ethmoid complex is scarcely ossified, except for the posterior upright border of the parethmoid. Considering the skull as a whole, the bony supports in the adult concerned with the receiving and absorption of the terrific side-swiping stresses of the sword, are only just beginning to be apparent in this young fish. The engulfing apparatus with its normal rows of

regular teeth is for the present a real working mechanism, rather than the anlage of a battering ram or broad-sword.

That portion of the supraoccipital and frontals covering the brain is almost without ossification and is quite transparent. The surface is covered with an infinite number of extremely minute spines or tubercles, visible only under high power. The hyomandibular, metapterygoid, symplectic and quadrate are all distinct and differ little from the corresponding bones in the adult skull.

Opercles: The preopercular is narrow, straight and upright, in shape and position thus resembling the corresponding bone in *Xiphias* rather than that of the adult *Istiophorus*. It is very strongly ossified anteriorly, and especially at the corner which supports the strong spine. The posterior part has almost no ossification at this stage. From the antero-superior facet of the opercle there springs a strongly ossified, radiating fan of body ridges, but the posterior part, overlying part of the pectoral arch, is scarcely defined. Only the upper edges of the three other opercular elements have taken up the bone stain.

Snout: The snout in this young specimen is only two and a half, not three times, contained in the standard body length. The sword has a decided upward curve throughout its length, and the flattening is not as apparent as in the 42 mm. young fish.

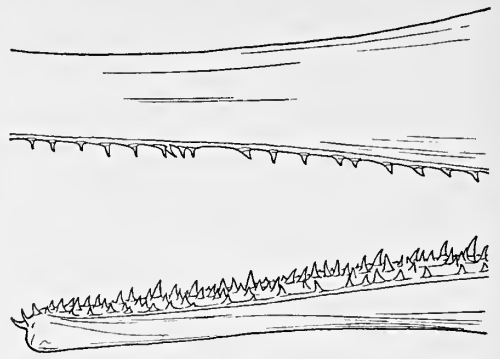
Teeth: The upper jaw is armed with a single row of well-developed wide-spaced teeth, about seventy in the basal 65% of the maxillary. The rest of the tip (10 mm.) is almost edentulous, with the slightest scattering of teeth, minute and quite adventitious as to location and regularity. At the very tip is a group of four or five enlarged teeth, which are directed outward and point in all directions. There are teeth throughout the entire length of the mandible, double rows in places, and much closer together and more numerous than are those of the upper jaw. They number 70 to 80 in a single row along one side. They increase slightly in size distally, until the tip is a mass of close-set fangs, with unusually large ones out-jutting from the extremity.

All these teeth are real, separate dental structures, easily detached, broad bases and all, and with nothing in common with the denticles of the adult fish. (Text-fig. 3.)

Vertebral Column: The vertebral column is fairly well ossified, although bony deposits are less apparent in the centra than in the neural and haemal arches and spines. There are 24 vertebrae, 12 pre-caudal and 12 caudal, and the adult characters in all are so distinctly adumbrated in faint osseous staining that they call for little comment.

The anterior neural zygopophyses of the 1st vertebra are very high and rounded, almost as conspicuous as the neural arch of the 2nd.

The specialized neural arch of the 2nd vertebra is relatively very large in this young individual, rising high above the succeeding arches and spines, appearing as a great up-reaching tongue of



Text-figure 3.

Teeth of 84 mm. *Istiophorus greyi*. $\times 18$.

bone lying close alongside the interneural of the 10th dorsal spine.

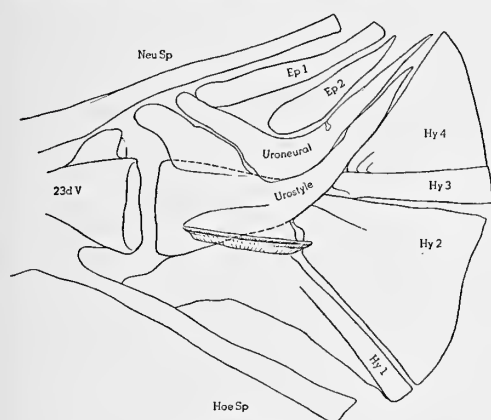
As we approach the tail there is a marked increase in strength of ossification of the neural and haemal spines and especially of the centra themselves. The 21st vertebra is the last morphologically unspecialized element of the column, although the 20th shows increased ossification. But from here to and including the 24th or urostyle, the scarlet staining shows a bony deposit equalled in strength only by that in the jaws and teeth. There is no doubt that these structures and localities are of greatest importance to the young fish of this age.

Ribs: The first two ribs arise from the 1st and 2nd postcranial vertebrae. They are identical with each other and quite unlike the succeeding elements. In size and general direction they bear more resemblance to epipleurals than to true ribs, but they arise however, from the centra in true rib fashion. They are about half the diameter of the following ribs, and curve sharply backward. The first ends close beneath the second, and the sharp curve of the latter takes it across the 3rd rib not far below its head. The succeeding ribs are the strongest ossified parts of the anterior axial skeleton. The maximum in size, length and curvature is reached in the 6th and 7th, while the 12th and last pair, situated just before the vertical of the anal opening, is short and almost straight. This pair is actually shorter than the succeeding corresponding elements forming the first haemal arch.

The location of origin of the ribs in relation to the dorsal fin elements is as follows: The 1st rib arises between the 5th and 6th spines; 2nd, 7-8; 3rd, 10-11; 4th, 13-14; 5th, 16-17; 6th, 19-20; 7th, 21-22; 8th, 24-25; 9th, 26-27; 10th, 28-29; 11th, 30-31; 12th, 32-33rd spines.

Caudal Vertebral Complex: In the 21st vertebra the neural and haemal spines are typical, except that they are somewhat narrower than the preceding ones. In the 22nd, specialization is extreme, and the neural spine, which has not yet ossified with the arch, has lengthened until it extends to a vertical of half across the centrum of

the urostyle, and underlies the anterior, four caudal raylets. The proximal half is a narrow flat leaf, which changes abruptly into a thin, sharp splinter, identical with the corresponding part of the equally elongated haemal spine. An interesting condition is the unossified base of the haemal process, together with the enlarged character of this element. (Text-fig. 4.)



Text-figure 4.

Caudal complex of 84 mm. *Istiophorus greyi*.
× 25.

The 23rd vertebra is very strongly ossified and less hour-glass shaped than the others. It possesses slender but well-developed anterior neural and haemal zygopophyses which perform their usual function. The haemal process is free from the centrum, the dorsal face of the process showing as a thin, wide-spread sheet of bone. The already large size of this structure, and its flaring edges anticipate the ultimate radical spreading of this bone, reaching up over more than half of the entire centrum, increasing its zygopophysial forward extensions, and swinging sharply backward, passing between the anterior haemal zygopophyses of the 24th vertebra, and in the adult, fusing its great blunt-headed spine with the 1st hypural.

Thus we have three distinct developments at this early age, in the neural and haemal spines of the 21st, 22nd, and 23rd vertebrae; in the 21st the spines are large, narrow, flattened leaves; in the 22nd both are reduced, with the distal halves needle-like; in the 23rd they are again enlarged and elongate, subequal throughout and truncate.

The 24th vertebra or urostyle is but little specialized in its anterior half, presenting a perfect half centrum and large, normal neural and haemal zygopophyses. From the side of the base of the haemal process arises a large, thin, fan-shaped, horizontal sheet of bone, the analogue of the lateral caudal process in the full-grown sailfish. It measures .7 mm. from front to back, equal to the length of the half centrum of the ultimate vertebra.

From the posterior end of this last centrum, the urostyle proper curves steeply upward as an ossified finger, its attenuated tip almost reaching the upper angle of the 3rd hypural, the upper element of the caudal fan.

The 24th vertebra sends strong, anterior haemal zygopophyses forward, enclosing the haemal spine of the 23rd. Each of these zygopophyses has a strongly ossified wing, below the haemal arch and between the zygopophysis and the 1st hypural. The latter is a strong, broad bone, rather wider at the tip than at its origin. It is quite free from the 2nd hypural, or lower caudal fan bone. The upper half of the caudal fan is separated almost to the base, from the lower half. A faint hint is observable of what in the 70 mm. fish is a distinct seam across the upper half of the hypural trail fan.

The 24th vertebra shows a rather small, specialized neural process with an anteriorly directed wing. Directly above it is a long, anterior branch of a free uroneural, which broadens out posteriorly and sends another arm up, parallel to and dorsal to the urostyle. This, in the adult *Xiphias* and *Istiophorus*, is called a hypural by Gregory and Conrad. It is, however, a paired bone and also superior to the urostyle, and hence is a typical uroneural. Above this bone are two free epurals. They extend full out to the contour of the caudal complex, and are stout and truncated. Their anterior ends fit into the area between the wide-spread arms and the body of the uroneural.

The next and last superior element in the caudal supporting complex is the broad, truncate, hypural-like, prolonged neural spine from the 23rd vertebra.

Dorsal Fin Bases: The first dorsal element is altogether subdermal, although it has a minute spine and a very small base, which is quite unattached. The spine of number two penetrates the skin, but only for the distance of .32 of a mm. It also has a very small and unattached base. The 3rd spine is 3 mm. long. It sends down a slender interneural which lies close in front of the succeeding interneural, but by far the major part of its subdermal process is a large, wide-spread bony fan which extends forward in the midline, a distance of 1.5 mm. over the exoccipitals and on well over the vertical of the supraoccipital.

From here on, posteriorly, the subdermal part of the dorsal fin shows little variation, the spines splaying out beneath the skin into a pair of flat, strong bony expanses, affording ample attachment to the interneural elements. These latter are transversely broad at the top, changing into a flattened, fore and aft blade at the lower end. In this young fish there are two separate elements in the interneural complex. One is short and cone-shaped, lying chiefly between the bases of the spines. It articulates loosely with the posterior base and extends almost straight forward, beneath the next element, notched on the way for articulation with the short posterior

spine of the latter. It finally articulates, end on, with the upper head of the interneural. These interneurals are almost vertical in the anterior dorsal elements, and the inter-basal bone is hardly apparent, although there is as yet no hint of the crowding together and actual ossification of these anterior interneurals in the adult fish. Posteriorly, the interneurals become shorter and more oblique until they are almost horizontal and no longer than the superior, inter-basal bone.

The posterior eight rays of the dorsal have their bases twice as close together as the preceding ones, and all but the last have a great bony sheet or thin, wing-like structure developed down and back from the oblique interneurals, reaching to and parallel with the upper line of the great leaf-like neural spines of the 18th and 19th vertebrae. The last ray, which is completely double, springs from a single base and has only a very small, horizontal subdermal bone as its base.

Anal Fin Bases: Subdermally, and judging by the interrelationship of the interhaemals, it is only the first 6 elements, 3 spines and 3 rays, which form a cohesive unit, and not 9, as we would assume from external observation. The 1st interhaemal is very large, triangular, with the broad base stretching forward along the body contour, almost to the anus, a distance nearly equal to the length of its spine. The succeeding interhaemals are all much alike, flattened, truncate, strongly ossified.

The anterior six slant slightly forward, but from the 7th back this angle is greatly increased, until up to the 17th, these bones are not far from the horizontal. From the 18th on, the bases, like those of the incipient 2nd dorsal, develop a great, thin wing which almost unites the group into one solid sheet. The exception is the last, double element, which has only a small, independent base. To avoid confusion with published counts of median fin elements of *Istiophorus*, I am considering the last double ray as one; but elsewhere in conformity with its evolutionary significance, I always recognize this double element as two rays.

Pectoral Girdle: The superior elements are not greatly unlike those of the adult. The posttemporal is distinctly three-pronged, more pronouncedly so than in the full-grown fish. The dorsal and ventral branches are much wider apart, giving the general external aspect of a turkey wishbone. The uppermost branch, connecting with the epiotic is narrow, rounded at the tip, and flattened horizontally. The median is long and slender, and connected with the fork by a wide, thin wing. Posteriorly there is a rounded, conspicuous angle into which the anterior head of the supraclithrum will fit, but which in the present stage of ossification appears quite isolated. Text-figs. 5 & 6).

The supraclithrum is a well-developed, blade-like bone, articulating with the flattened base of the posttemporal. It extends down and slightly back from the vertical and overlies the superior prong and the posterior flaring wing of the

cleithrum. The two external toothed ridges, so conspicuous on the head of the 42 mm. sailfish, are still seen projecting above the skin. One is ossified with the upper, posterior edge of the head of the supraclithrum, and the other to the external basal neck of the posttemporal. In the adult bones, vestigial remains of both ridges can still be detected, especially in the series of teeth on the upper posterior knife-edge of the supraclithrum.

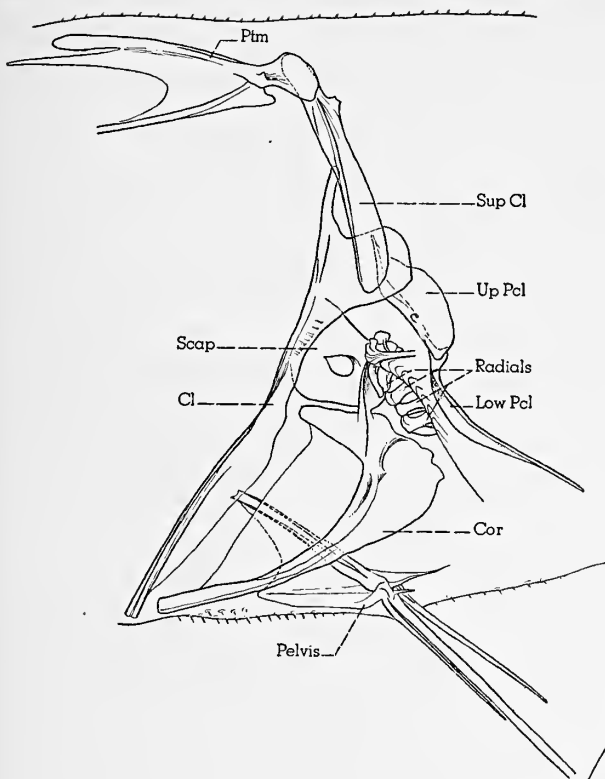
The cleithrum shows less of the antero-posterior wing-like extension than it will later on, and the superior finger is relatively longer. From the base of this extension the cleithrum extends down and forward for more than three-fourths of its entire length as a long, thin rod, reaching the body contour, behind the posterior ends of several branchiostegals, and well ossified throughout. But there is no hint of the overlying extension which later will curve partly over the scapular and only an imperfect hint of the future thin sheet of bone which will completely close the cleithrum-coracoid interspace.

Underlying both the ventral tip of the supraclithrum and the posterior wing of the cleithrum is the upper postcleithrum. This consists of an anterior thickened, rodlike margin flaring out behind into a broad, oval sheet of bony tissue. It extends down and back to beneath the first pectoral spine. Closely articulated with the lower end of this marginal rod is the lower postcleithrum. This is half again as long as the upper element, and describes a long, sweeping curve behind and below the pectoral rays, slightly flattened anteriorly along its basal half, but thinning out into an elongate spine at the distal end.

The scapular is shaped much as in the adult bone, but the coracoid preserves its primitive, elongate, curved, rodlike character, except for a posterior wing flaring out from the proximal half, and an anterior tongue of thin bone paralleling the ventral aspect of the scapular. The lower, forward extension of the coracoid falls short of the corresponding end of the cleithrum. The actinosts are difficult to discern clearly but there are certainly five, all ossified, the uppermost oblique one extending back from the base of the stout, pectoral spine, and intimately connected with the posterior border of the scapular.

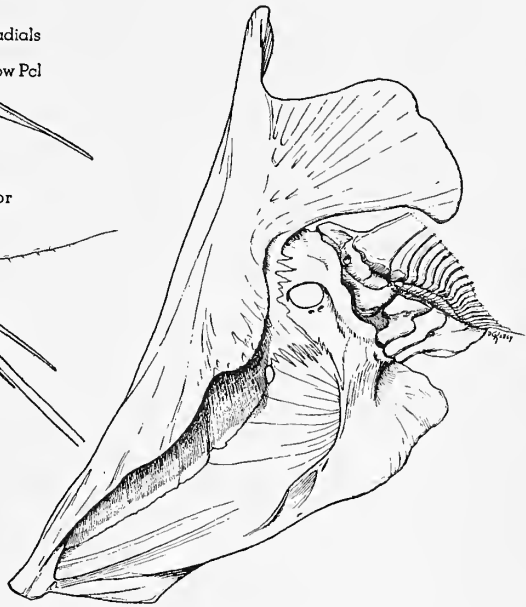
Pelvic Girdle: This well-ossified and muscled girdle indicates an active usefulness of the external fins to which we have as yet no exact knowledge or clue. Each fin consists superficially of a spine and two rays, one of the latter being very greatly elongated. These all arise from a relatively small, bony, subdermal base from which in turn spring several diverse elements. Anteriorly, from the spine side, a thin bony fan extends for a short distance forward and down. Superiorly and obliquely forward, two long slender spines reach up between the coracoids, and on across the almost empty intervening space, nearly to the mid-portion of the cleithrum.

Posteriorly a shorter, stouter spine or style is



Text-figure 5.

Pectoral and pelvic girdles of 84 mm.
Istiophorus greyi. $\times 12$.



Text-figure 6.

Pectoral girdle of adult *Istiophorus*
americanus. Reduced $1\frac{3}{4}$.

directed backward, connected with the pelvic base by a wide, thin bony fan or wing. Below this, and arising from the base itself is a second, shorter spine. The external pelvic spine proper is closely applied to the first elongate ray, while the shorter ray, although attached by webbing to the long one, is freely movable, and has a separate origin, arising not from the bony complex, but from the base of the posterior style.

The base doubtless consists of several radials or actinosts, but nothing can be decided with certainty until both younger and older specimens are available.

Istiophorus americanus Cuvier & Valenciennes.

Atlantic Sailfish.

Material Studied: One young specimen, standard length 70 mm., from Florida. Cat. No. 28,932. KOH No. 2330. Presented by Duncan Holmes, August 12, 1938.

Note: This specimen was in bad condition, many of the spines and rays being partly lacking and the webs torn. The young fish has been cleared and stained. Its description will consist only of comparison with the 42 and 84 mm. specimens from the Pacific. Its standard length is 83% that of the latter.

Color: As this fish was in alcohol for some time before coming into my hands, all definite color, both of the body and fins, has disappeared. The dorsal fin shows considerable brown pigment but no pattern.

Food: In the stomach of this young sailfish there was a larval fish, bitten in half, about 15 mm. in length. The urostyle with four, large, separate hypurals indicates extreme youth, and the character of the vertebrae is distinctly clupeoid. In addition to this, seventeen copepods were present (Cat. No. 4,058). These were as follows: 1 *Oncaea* sp.; 1 *Oithona* (male) sp.; 15 *Farranula rostrata*. The latter had been swal-

lowed whole, and were so undamaged that there was no doubt even about the species.

Dr. Charles B. Wilson, who kindly identified these for me, writes interestingly as follows: "I have gradually come to regard the copepods as holding the same relation to the fishes, that milk does to the mammals. No matter what the ultimate food of the adult may be, the newly born young subsist for a time upon the same food: milk for mammals and copepods for fish. This is the first baby of any of the large carnivorous fish whose stomach contents I have had the privilege of examining, and it is gratifying to find that they start by feeding in part at least upon some of the very smallest of the tropical surface copepods."

Measurements: Total length 74.3 mm.; standard length 70; depth at pectoral 5.7; head 37; eyeball 3.4; snout 29.3; snout to first dorsal 29.3; snout to pectorals 36.6; snout to pelvics 39; maxillary 32; lower jaw-tip to snout-tip 21; upper pterotic spine 1; lower preopercular spine 3; dorsal height, fifteenth spine 20; caudal lobes 5.7; middle caudal rays 2; pelvic spine 1.75; pelvic elongate ray 13.4; pelvic short ray 2 mm.

Counts: Dorsal count $5 + 36 + 7 + 8 = 56$; caudal count $12 + 7 + 8 + 12 = 39$; pectoral count $1 + 18 = 19$; pelvic count $1 + 3 = 4$.

General Body Form: At the vertical of the pectoral origin, which is the least distorted part of the body, the depth is 5.6 mm., giving a relation of about eleven times in the body length.

Skin: The distribution and the general character of the body scales is exactly like the Pacific species, but the scales themselves are decidedly less developed. They are smaller and the central clear area is larger, and the spines are unexpectedly low, thick and blunt. This character is much more than we should expect in a fish only 17% less in length than the other. The largest scale is .2 mm. in diameter.

Lateral Line: The lateral line scales separating the long series of openings are distinct from the scales proper in possessing irregular thickenings on the surface. These are usually in two ragged lines or patches of rugosities across the upper and lower parts of the scale. None of the adjacent scales, above or below, are thus marked.

Cephalic Ridge and Spines: The serrated cephalic ridge over the eye is less developed, as is also the upper spine, but the lower one is longer than in either the 42 or the 84 mm. individuals. The upper spine very definitely arises from the external ridge and posterior end of the pterotic, overlying the point of attachment of the lower branch of the posttemporal. The lower, preopercular spine is very strong but only slightly serrated. It measures 3 mm. in length.

Dorsal Fin: In spite of the damage incurred, we can see that this fin was continuous and contained 56 elements, as in the 84 mm. fish. The same four divisions are evident, the relative numbers being $5 + 36 + 7 + 8$. Numbers 1 and 2 are subdermal at this stage, and in an uncleared specimen would not be distinguishable. The

first 5 are true spines, separated from the succeeding elements by an even greater distinction in relative length of the 5th and 6th elements. Basally, there is another local grouping, elements 4 to 8 inclusive, whose bases and origins are very close together. The 6th to 37th ray-like spines compose the large part of the fin. The succeeding 6 are marked off by being shorter and more delicate, and will be among those lost in the adult. The posterior 8 are typical rays, close together, possess strong and deep supporting, subdermal bases, and will form the ultimately isolated 2nd dorsal.

Anal Fin: This is too damaged, even as to the bases, to count accurately. Twenty-two elements can be made out and there were probably several more.

Caudal Fin: Although considerably damaged, the caudal count can be made out to be identical with that of the 84 mm. fish, except that the central upper and lower halves are 7 and 8 respectively instead of 8 and 7.

Pectoral Fin: The pectoral formula is I-18. This fin is relatively smaller than in either of the Pacific baby sailfishes; 6.6% to the standard length, as compared with 10% and 7.6%. The rays articulate (distantly, at this stage) with four free radials; the two central ones more slender and flaring slightly at top and bottom; the outermost with an expanse of thin, external wing, and articulating closely at one side, with the outer shoulder of the coracoid. The innermost of the four contacts the postero-inferior angle of a 5th radial. The base of the pectoral spine is enlarged, and is intimately faceted with the upper end of this long, angular 5th radial, which is partly ossified with the posterior border of the scapular.

Pelvic Fin: The elongate pelvic rays are split 4.8 mm. from the tips, more than a third of their length, the split being normal, a character not apparent in either of the young Pacific fish. Almost at the point of division, the free tip of what appears to be a 3rd ray is visible, becoming at once merged with the larger stem.

Skull: The bones are slightly more distinct than in the larger fish, about as much as we should expect. The relation of the frontal, nasal, maxillary and premaxillary is as already described, as Gregory has deduced from the adult, and excellently illustrated.

Opercles: These bones are more strongly ossified than in the larger fish, and the opercle is distinct as far back as the base of the pectoral.

Teeth: There is no edentulous area in the upper jaw.

Caudal Complex: The general condition as compared with that in the 84 mm. fish shows slightly more separation of the various elements. One radical difference is the division of the upper half of the caudal fan bone, into two hypurals by a strong, transverse seam, which however, is not open. It extends clear across the bone, about one-fourth of the way up from the midline division. The separation between the two halves of

the central hypurals is complete, extending clear down to the urostyle. Several vertebral divisions are faintly distinguishable near the base of the urostyle finger itself.

Dorsal Fin Bases: These are relatively much less ossified than they are in the 84 mm. specimen. At this stage, there can be very little muscle attachment for control of the great expanse of spines and webbing.

Pectoral Girdle: This is the most strongly ossified of all the fin bases. Even this young fish must have some important use for this elongate, narrow fin, although, as we have seen, the long rays are split into two branches for a full third of their length.

Istiophorus greyi Jordan & Hill.

Material Studied: Full grown male, of 2,616 mm. standard length, 2,946 mm. total length (nine feet, eight inches) over all; taken trolling with feather jig, 5:30 P. M. February 8, 1938, on the Eastern Pacific Zaca Expedition; Station 210, 9° 12' North Lat., 85° 5' West Long., twenty miles south of Cape Blanco, Costa Rica. Cat. No. 28,308; photographs 9081 and 9082; weight 115 pounds.

Color: Typical Pacific sailfish coloration, deep blue on upper half of body and along base of dorsal; with about twenty vertical pale bands down sides, some broken into a series of large whitish spots. Sail perfect, very large, deeply incised in the anterior portion; covered with small, blue spots.

Size and Weight: The following six Pacific fish give an average relation of length and weight for adult fish. The lengths are total:

2,730 mm.	78 pounds
2,743 mm.	92 pounds
2,781 mm.	100 pounds
2,794 mm.	94 pounds
2,946 mm.	115 pounds
2,965 mm.	117 pounds
3,073 mm.	130 pounds

Food: Seven small squids, 50 to 100 mm. long; one large squid with very large caudal fin, body 300 mm., with the caudal fin 120 mm. wide. Also a two-inch paper nautilus, shell and inmate (No. 38,211), and a 40 mm. *Chaetodon humeralis*, both quite uninjured.

A one-hundred-pound sailfish taken in the Pearl Islands, Panama Bay, had eaten five, eight-inch *Caranx caninus*.

Parasites: Only a single free copepod on the whole body of the sailfish, but clusters of slender parasitic copepods with brush-like gills at the distal end (Photograph 9083). Two of these clusters has several bright colored barnacles growing tightly to each stem. Those which carried no barnacles, trailed tremendously long and very thin threads of eggs. They are probably *Penella filosa* (Linnaeus).

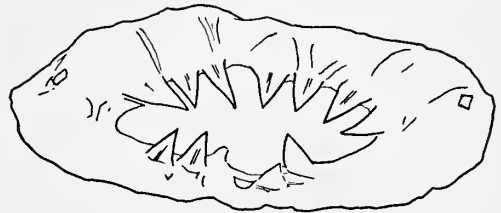
Measurements: Total length 2,946 mm.; standard length 2,616; depth at pectoral 304; depth at first dorsal 331; depth at second dorsal 183; depth at peduncle 63; head 889; eyeball 53; iris, horizontal 41; iris, vertical 35; snout 599; snout to first dorsal 801; snout to pectorals 915; snout to pelvics 965; maxillary 686; lower jaw 279; lower jaw-tip to snout-tip 292; nostril to eye 25; anus in front of first anal 150; interdorsal width 77; first dorsal base 1,397; first dorsal height, first spine 496; first dorsal height, 15th spine, 1,003; dorsal sheath depth 51; first anal base 51; first anal height 234; second anal base 88; second anal height 77; caudal lobes spread 934; upper caudal lobe 546; lower caudal lobe 537; pectoral length 419; pectoral base 100; pelvic length 667 mm.

Counts: first dorsal count 3 + 36 + (6) = 39; second dorsal 7; first anal 2 + 11 = 13; second anal 6.

Skin: Much of the skin of the adult sailfish is covered with a multitude of minute mucous openings, sometimes in parallel lines. Many of these are surrounded by a well ossified, but tissue-thin plate or scale, oval or rounded, and easily detached. If the central portion lies over a mucous opening it is perforated, doughnut-like. Often the scale is a hemicircle or a small irregular piece, but when perfect it is rounded and perforated. On other large areas of the skin, these protective scales are found in all shapes, sizes and frequencies, or again for several inches, they may be in regular lines.

Under high power, a typical, elongate oval, guard scale is seen to have the surface covered with a mass of low, blunt tubercles, presenting a rough, crystalline appearance. The center is perforated with a large, oblong hole, and around this are grouped eleven enlarged, thick, sharp spines or teeth. Eight along the upper edge grow horizontally out and over the rim of the opening, completely protecting that side. On the opposite side are three slightly larger spines, more nearly vertical, also pointing over the edge but obliquely upward. This scale measured .45 long by .23 mm. wide. These toothed scales seem to be placed more regularly and to protect openings larger and of different origin from the multitudinous small mucous vents. (Text-fig. 7.)

The second type of adult scale is a stiff scute, strongly ossified, irregularly abundant, sometimes completely buried in the epidermis, more



Text-figure 7.

Mucous canal guard of 2,616 mm. *Istiophorus greyi*. $\times 15$.

often half exposed. These all lie with their long axes longitudinal to the fish. They vary considerably in shape, but the commonest type is rounded at one end (the anterior or concealed end) and tapering slowly to a blunt point at the other end. These scales vary from 9 to 15 mm. and may occur in several depths of epidermal and dermal strata. The surface is covered with a succession of fine lines like those on an ordinary fish scale. These all focus on the center of the round end, giving an exact imitation of a thumb print. In a scale 3 by 10 mm. there were forty-three concentric lines between the center and the periphery of the round end. The lines are distinct as such, but they are also minutely beaded with rugosities. In one unidentified area of skin, these scutes were in the form of long, narrow splinters, 25 or more mm. in length, and lying close together well below the surface, forming an almost solid armor. (Text-fig. 8, and Plate III, fig. 6.)



Text-figure 8.

Dermal scute of 2,616 mm. *Istiophorus greyi*.
× 6.5.

Teeth: The denticles on the jaws of the adult sailfish are short, stout, translucent white, sharp-pointed and slightly curved. They are very small, varying from .3 to .7 of a mm. Their arrangement is wholly irregular, their average distance apart being about their own height. In an area 4 by 4 mm. square, there were 42 denticles. They are very strongly inserted, and where they are lost, there remains a deep, round hole. (Plate IV, fig. 7.)

On the mandible and on the maxillary as far as the tip of the lower jaw, the denticles are confined to two broad bands about 12 mm. wide. The mandibular band is strongly transversely curved but horizontal, while that of the upper jaw is very flat and oblique, sloping up and outward. In each case the denticular band is raised above the surface of the adjacent surface of the jaw. Beyond the tip of the mandible, the maxillary band widens at once, and encroaches upon the ventral and dorsal surfaces until, in the distal third, the surface of the bone is completely covered. As the upper jaw becomes more and more flattened, dorso-ventrally, the strongest denticles come to be concentrated along the lateral edges, those above and below being smaller, more stub-like.

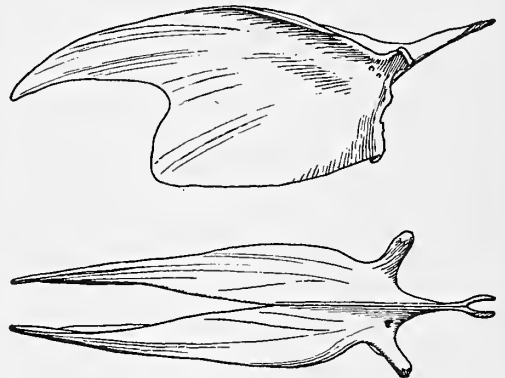
Pectoral Spine: This is a true spine, but when dry, it splits into longitudinal halves near the tip. This splitting bears no resemblance to the lateral dividing, natural to the other pectoral elements, which are true rays.

Anal Fin: Unlike some other Pacific specimens which I have examined, this individual had the first and the last rays of the second dorsal and second anal very considerably elongated.

Pelvic Fin: In the pelvic fin of the full-grown sailfish, the spine is usually very distinct, although closely applied to the base of the elongate ray. The spine is relatively smaller compared with this ray; 1 to 26 in the adult and 1 to 9 in the 84 mm. fish. At the base the spines are solidly ossified with a large, irregular transverse bone. From a hollow in this bone, arise two large rays. In one fin I examined these amalgamated and fused with one another more and more throughout the length of what appears usually to be a single, greatly elongated ray. In another specimen two additional, short, free rays were present, concealed between the bases of the fins. I have not had a chance to dissect out the last free ray (usually recognized as the 2nd).

In certain individuals the full complement of one spine and four rays seems to be present. Yet the elongate single or double ray has a deep, long dermal sheath provided for it and a very considerable expanse of webbing throughout its entire length. (Plate IV, fig. 8.)

Pelvic Arch: The adult pelvis is compact and complex, a single large bone with expanded, wing-like anterior portion, and a smaller, superior flange, flaring out inwardly and horizontally, just below the curved upper surface of the main bone. Posteriorly there arises a prominent, slender style. The pronounced superior curve and the great expanse of wing make it unlike the pelvis of any other family of scombroids. This whole affair is duplicated, and the two are joined together by the enlarged area of the horizontal flange, together with the base of the style. The fin itself is attached to a transverse, thickened area which articulates with the transverse base of the pelvic spine. The full length of the pelvic arch as compared with the elongated ray is as 1 to 6, whereas in the young fish it is 1 to 10. (Text-fig. 9.)



Text-figure 9.

Pelvic girdle of adult *Istiophorus americanus*.
Reduced $1\frac{1}{2}$.

SUMMARY AND CONCLUSIONS.

General: A most significant feature, evident at first glance at the three young sailfish, of 42, 70 and 84 mm. standard lengths, is that in spite of their diminutive size, they are, externally, absurdly like the full-grown adult fish. The greatly elongated upper jaw and pelvic fins, the enormous expanse of dorsal fin, are as characteristic of the 42 mm. specimen as they are of the adult fish more than sixty times as long.

When, however, we add to these externals of the normal opaque fish, the skeleton and other internal characters, we realize that there is little or no hint of the radical changes to come. The absence of intermediate material, such as two- or three-foot sailfish, only emphasizes that these young fish are isolated, well-balanced, efficiently functioning organisms in their own right. Like most typical fish they are covered with scales, their jaws are filled with teeth of ordinary pattern, and their two specialized fins impose no unusual activities or habits.

There is no hint of the subsequent complete disappearance of the armor of scales, and their replacement with minute mucous canal guards and bony scutes. Without having ever seen the full-grown fish we would never know that the teeth would all fall out, with the substitution of uncounted, cruelly sharp and strong denticles, covering the entire sword.

With this radical change in the dental armature of the snout, and the consequent shift from a prehensile snapping, to a slashing method of attack and feeding, the entire head and body will undergo vital changes. A mobile, twisting body will alter to a stiffened, recoil-guarded handle to the great sword; the parietal and other regions of the skull, the vertebrae and caudal complex, the fin bases, the pectoral arch—all will witness an ontogenetic swift and thorough thickening and extension of ossification. All joints will be stiffened, until the whole becomes a taut, tense spring, an organic engine to generate and direct the terrific ramming, hitting and slashing power of the solidly denticled sword.

In the young fish all this excess of bone formation is held in abeyance, adumbrated only, so that the toothed, scaled, prehensile stage of development may function as perfectly as though it would persist throughout the entire lifetime of the fish.

Scale Comparison of Young Xiphias with Istiophorus: The scales of a young *Xiphias gladius* of 87 mm. standard length (loaned by the American Museum of Natural History) are wholly unlike those of *Istiophorus* of corresponding size (84 mm.). In *Xiphias* all are of one general pattern, with broad, flat, irregular base, the periphery deeply incised, stellate, with many sharp points. Those covering the body as a whole, are small, with commonly two (rarely one or three) slender, sharp, straight spines. These scales form narrowly spaced longitudinal

rows along the sides. The second type of scale is arranged in eight rows, four on each side of the body, all rather near the unpaired fins; those nearest being decidedly the largest. Each scale slopes up to a narrow central ridge, along which are usually four (rarely three or five) compressed, thick, backward curved, talon-like spines. The most unexpected thing about these is that they are fully webbed to the tips, like diminutive, unpaired fin spines.

In a smaller *Xiphias* of 40 mm. (No. 28,933) there is much less differentiation between the two types of scales, the whole body being densely clothed with the smaller ones. The character of these scales is as unlike those in young *Istiophorus* as those of the larger *Xiphias*.

Comparative Measurements: The accompanying table gives the relative percentages of measurements in four sailfish, with standard lengths of 42, 70, 84 and 2,616 mm. Although in outward general appearance even the smallest and the largest are extremely alike, yet the smallest is only 1.6 percent of the standard length of the largest, while its weight is 194,190 times less than that of the adult.

The depths of the four fish show little change, the extremes at the vertical of the origin of the dorsal being 10 and 12.7% (always considering the smallest fish first), and those at the peduncle being even closer.

The head is considerably larger in the three young, more than half the length of the fish, while it diminishes to a third in the adult. The eye, as so often the case, is larger in the immature fish, the relative decrease being one-half to two-thirds. The three measurements of snout to dorsal, pectorals and pelvics are relatively similar, all more than half the standard length in the young and decreasing to one-third in the old one. Both the maxillary and the lower jaw show similar but less extreme reductions. The cephalic spines show diminution even from the 42 to the 70 mm. ages, and of course are wholly lacking in the oldest individual. The greatest height of the dorsal presents little relative growth change, the two extremes being 32 and 38.4%.

There is radical change in the caudal fin. The length of the lobes shift from 10% in the smallest infant, to 20 in the adult, and the spread of the fin is still more marked, 7.8 to 35%. Greatest of all are the changes in comparative lengths of the middle and outer caudal rays, from 85% in the more normally shaped tail of the small fish to only 10.5% in the mighty crescent of the full-grown sailfish. The pectoral length increases from 10 to 16%. The pelvic spine, although short and consolidated in the young (2.5 to 3.5%), becomes of even less importance in the old fish, a mere seven-tenths of 1%. The length of the elongate pelvic ray shows considerable variation in the young fish themselves, from 10% in the 70 mm. Florida specimen, to 26% in the 42 mm. baby. In the adult sailfish this elongate ray has increased only to 30%.

	Percentages in Standard Length.			
Total length.....	46.5 mm.	74.3 mm.	91 mm.	2,946 mm.
Standard length.....	42 mm.	70 mm.	84 mm.	2,616 mm.
Depth at pectoral.....	10%	8%	7.6%	11.6%
Depth at dorsal.....	10		8	12.7
Depth at peduncle.....	3	2	2	2.4
Head.....	51.6	53	53	34
Eye-ball.....	6.6	4.8	4.7	2
Snout.....	35.7	42	41	23
Snout to dorsal.....	50	52	51.7	30.6
Snout to pectorals.....	52.4	55.7	54	35
Snout to pelvics.....	52.8	56	54.8	37
Maxillary.....	42.8	45.7	46	26
Lower jaw.....	19	18	16.7	10.7
Lower jaw to snout tip.....	22.6	30	30	11
Upper pterotic spine.....	4	1.4	1.6	—
Lower preopercular spine.....	6.6	4.3	3	—
Dorsal height, 15th spine.....	32		33	38.4
1st anal lobe height.....	5		4	9
1st anal lobe base.....	3.5		2.8	8.6
2nd anal lobe height.....	2.4		2	3
2nd anal lobe base.....	2.4		2.8	3.4
Caudal fin spread.....	7.8		12.8	35.7
Upper caudal lobe.....	10	8	10	21
Lower caudal lobe.....	11		10	20.5
Mid. caudal rays.....	85		87	10.5
Pectoral length.....	10	6.6	7.6	16
Pelvic spine.....	3.5	2.5	2.6	.7
Pelvic 1st ray.....	26	10	23.8	30
Pelvic 2nd ray.....	5.5	3	3.8	

Antero-posterior Growth Increase: To illustrate the well-known antero-posterior extension of various parts of the skeleton of the sailfish, the vertebral comparison of young with adult must suffice. This shows the very marked shift in proportions during post-larval ontogenetic development. This table shows the relative proportions of times height in length, of eight vertebral centra in the 84 mm. fish and an adult.

Vertebrae	84 mm.	Adult.
5th vertebra.....	2	2.3
10th vertebra.....	2	3.6
13th vertebra.....	2	3.1
15th vertebra.....	1.8	4
18th vertebra.....	1.7	4.1
20th vertebra.....	1.4	4.6
22nd vertebra.....	1.8	3
23rd vertebra.....	1.8	2.5

Unpaired Fin Counts: The following comparative dorsal and anal fin counts of various growth stages are taken from illustrations, as well as from skins and mounted specimens, and from the freshly caught fish which I have studied. I present the data chiefly to show how weak and unreliable a character for systematic specific differentiation is the count of the elements of the unpaired fins.

Shape of Dorsal: A character which, in my material, is shown only by extremes, is the general profile of the dorsal. In the young fish of 42 and 84 mm., the great sail is almost a perfect hemicycle, highest in the center, where the 15th ray or thereabouts is the longest. In the adults, both Atlantic and Pacific, there is a deep notch in the anterior third of the distal profile. There is no hint of this in the young, not even an incipient

weakness in the distal portions of the elements, such as is evident in that posterior section destined for obliteration in the full-grown sailfish.

Teeth: Correlated with what we have found to be true of the body scales, there seems no connection whatever between the normal piscine teeth of the young sailfish, arising in a dominant single row along the edge of the jaws from broad, flat, easily detachable bases, and the solid, irregularly distributed, tusk-like denticles of the full-grown fish.

No material is available for showing any transitional stages. Except for the sensible loss of some distal maxillary teeth in my 84 mm. specimen there is no evidence of any coming, radical change.

Food: The most striking thing about the food of the young sailfish is the similarity of diet in both Atlantic and Pacific individuals. In each there was a skeleton of a very young shore fish, in one case certainly, and in the other probably, a clupeoid. The remaining food was exclusively copepods, and copepods belonging to the very smallest of the tropical surface forms, all within the suborder Cyclopoida, characterized, at least in *Farranula* and *Corycaeus*, by very large, forwardly-directed eyes. Most of these copepods are extremely small species, less than a millimetre in length.

While the small fish food was bitten in two, the copepods had been swallowed whole, the solid rows of young sailfish teeth having wrought no damage whatever. The dominant copepod food of the Atlantic fish consisted of *Farranula rostrata*, while that of the Pacific individual was *Farranula gibbula*. These two young sailfish were taken in different oceans, separated by twelve

mm.		Dorsal Counts.	
5	Undifferentiated		Atlantic (Lutken, 1880)
9	"A low fringe."		Atlantic (Günther, 1873-4)
14	21	= 21	Atlantic (Günther, 1873-4)
42	5 + 35 + 6 + 9	= 55	Pacific (Beebe, page 210)
70	5 + 36 + 7 + 8	= 56	Atlantic (Beebe, page 219)
84	(1)4 + 37 + 6 + 8	= 56	Pacific (Beebe, page 213)
108	3 + 45 + 8	= 56	Atlantic (Cuvier, 1831)
457	2 + 45 + 7	= 54	Red Sea (Ruppell, 1841)
Adult	3 + 30 (7 subdermal)	7 = 47	Atlantic (Goode, 1883)
Adult	41 (Space)	7 = 48	Atlantic (Jord. & Ever., 1896)
Adult	40 (6 Stubs)	7 = 47	Atlantic (Amer. Mus. skin)
Adult	40 (6 Stubs)	7 = 47	Atlantic (Amer. Mus. skin)
Adult	34 (Space)	8 = 42	Pacific (Panama, Mounted)
Adult	33 (13 Stubs)	7 = 40	Pacific (Panama, mounted)
2616	3 + 36 (6 Stubs)	7 = 46	Pacific (Beebe, page 221)

Anal Counts

5	Undifferentiated		Atlantic (Lutken, 1880)
9	Undifferentiated		Atlantic (Günther, 1873-4)
14	13	= 13	Atlantic (Günther, 1873-4)
42	11 + 7 + 8	= 26	Pacific (Beebe, page 210)
84	9 + 8 + 8	= 25	Pacific (Beebe, page 213)
108	12 + 8 + 8	= 28	Atlantic (Cuvier, 1831)
457	10 (Space)	7 = 17	Red Sea (Ruppell, 1841)
Adult	11 (9 Stubs)	7 = 18	Atlantic (Goode, 1883)
Adult	9 (Space)	7 = 16	Atlantic (Jord. & Ever., 1896)
Adult	9 (Space)	8 = 17	Pacific (Panama, mounted)
Adult	9 (Space)	8 = 17	Pacific (Panama, mounted)
2616	2 + 11 (Space)	6 = 19	Pacific (Beebe, page 221)

hundred miles of longitude, and six hundred of latitude.

The adult fish is commonly reputed to obtain its food by using the snout like a slashing broadsword, yet the fish and squid food which I have examined, together with such delicate objects as the shell of a paper nautilus, were all swallowed whole and undamaged.

Diagnostic Characters: In the young fish two characters only stand out as even faintly diagnostic. In the 70 mm. Atlantic fish, the scale spines are short, thick and blunt, not long and slender as in the 42 and 84 mm. Pacific sailfish. The former has a slightly shorter pectoral fin, 6.6% of the standard length, not 7.6 and 10% as in the two latter young fish.

Characters of Growth Stages: For what they are worth, I present a summary of a few characters taken from a series of growth stages, from illustrations and from my specimens. It is possible that several of these may belong to different genera, but their very inconsistencies will be of value when a complete series of newly caught young fish is available. Text-figure 1, a-j. Page 210.

Length 5.5 mm. (Lütken, 1880).

Jaws equal.

Completely toothed.

Lower spine as long as jaws.

Dorsal, a long finfold.

Pectorals, large and rounded.

Pelvis, rudimentary.

Length 9 mm. (Günther, 1873-74).

Jaws equal.

Completely toothed.

Lower spine equals jaws.

Dorsal, a long, low fringe.

Pectorals, large and angular.

Pelvis, short buds.

Length 14 mm. (Günther, 1873-74).

Upper jaw slightly the longer.

Completely toothed.

Lower spine equals jaws.

Dorsal high, equal to snout.

Pectorals rounded.

Pelvis elongate filaments.

Length 16.5 mm. (LaMonte & Marcy, 1941).

Upper jaw slightly the longer.

Completely toothed.

Lower spine $\frac{2}{3}$ of jaws.

Dorsal high, equal to jaws.

Pectorals angular.

Pelvis elongate filaments.

Length 42 mm. (page 210).

Upper jaw $2\frac{1}{4}$ long as lower.

Completely toothed.

Lower spine equals eye.

Dorsal very high, rounded.

Pectorals large, rounded.

Pelvis elongate, $\frac{3}{4}$ snout.

Length 60 mm. (Günther, 1873-74).

Upper jaw twice lower.

Lower spine $1\frac{1}{2}$ eye.

Dorsal higher in front.

Pectorals long, rounded.

Pelvis moderate filaments, $2\frac{1}{2}$ eye.

Length 84 mm. (page 213).

Upper jaw 2.7 times lower.
Tip of upper edentulous.
Lower spine $1\frac{1}{2}$ in eye.
Dorsal high, rounded.
Pectorals moderate, angular.
Pelvics elongate, 1.4 in lower jaw.

Length 108 mm. (Cuvier, 1831).

Upper jaw $2\frac{1}{2}$ lower.
Tip of upper edentulous.
Lower spine $\frac{1}{2}$ eye.
Dorsal high, sloping back.
Pectorals long, slightly falcate.
Pelvics longer than lower jaw.

Length 457 mm. (Ruppell, 1841).

Upper jaw $1\frac{1}{2}$ lower.
Completely toothed.
No spine.
Dorsal very high, rounded.
Pectorals small, angular.
Pelvics equal dorsal height.

Length 2616 mm. (page 221).

Upper jaw $2\frac{1}{2}$ times lower.
No teeth, replaced by denticles.
Dorsal with deep anterior notch.
Pectorals falcate, long.
Pelvics nearly equal upper jaw.

Istiophorus americanus

As this article was going into final page proof, Miss Lyle McCaleb sent me a beautiful photograph of a young sailfish taken by Aubrey Nelson at Aransas Pass, Texas, August 31, 1941, said to weigh less than a pound, and to measure 20 inches in total length. The fish has been mounted, so is not available for study, but many details are distinct in the photograph (Plate V, Fig. 9).

It compares very closely with the illustration of Ruppell's specimen of 457 mm. (*Trans. Zool. Soc. London*, II, 1841, p. 71, Plate 15). Together with that fish it exhibits an adult contour of the caudal fin, wholly unlike the tail of all smaller individuals.

From the excellent photograph I have been able to make out the following percentages, all of the standard length of 437 mm. Depth 9.5%; head 38.6; eye 2.74; snout 32; maxillary 34.8; lower jaw 14.4; upper jaw overhang 21.6; pectoral length 7.2; dorsal height 29.7%. The pelvics are partly buried in their sheath, so cannot be correctly estimated.

These measurements resolve as follows, as compared with sailfish of 42 mm., 84 mm. and 2,616 mm. standard lengths: the head is much nearer that of the adult, as is the size of the eye; the snout is like the smallest, but the lower jaw is median in proportion; the jaw overhang is

close to that in the 42 mm. fish, but the pectoral length corresponds to the fin of the 84 mm. sailfish.

The exact shape of the dorsal fin is uncertain, but it appears to show little of the adult, anterior, profile depression. Forty elements are distinguishable back to the short posterior rays, and the interval between the future first and second dorsals is occupied by short, webbed stubs. Teeth are faintly visible in both jaws, at least as far as the tip of the lower; spines are absent, and the pectorals seem quite falcate.

For comparison with the ten growth stages I have shown in Text-figure 1, I offer the following caption:

437 mm. (Texas, 1941).

Upper jaw 2.4 times lower.
Jaws proper toothed, snout uncertain.
No spines.
Dorsal high and rounded.
Pectorals falcate.
Pelvics equal one-half head.

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EXPLANATION OF THE PLATES.

PLATE I.

- Fig. 1. *Istiophorus greyi*, 42 mm., photographed at moment of death. $\times 2.7$.
 Fig. 2. *Istiophorus greyi*, 42 mm., from a drawing from life by George Swanson. $\times 2$.

PLATE II.

- Fig. 3. *Istiophorus greyi*, 84 mm., photographed at moment of death. $\times 1.2$.
 Fig. 4. *Istiophorus greyi*, 84 mm., from a drawing from life by George Swanson. $\times 1.5$.

PLATE III.

- Fig. 5. Scales of 84 mm. *Istiophorus greyi*. $\times 18$.

- Fig. 6. Dermal scute of 2,616 mm. *Istiophorus greyi*. $\times 10$.

PLATE IV.

- Fig. 7. Rostral denticles of 2,616 mm. *Istiophorus greyi*. $\times 12$.
 Fig. 8. Pelvic fins of 2,616 mm. *Istiophorus greyi*. (Reduced 5).

PLATE V.

- Fig. 9. *Istiophorus americanus*, 20 inches total length, 437 mm. standard length, taken 3 miles off Aransas Pass, Texas, August 31, 1941, by Aubrey Nelson. (Reduced 3.5).

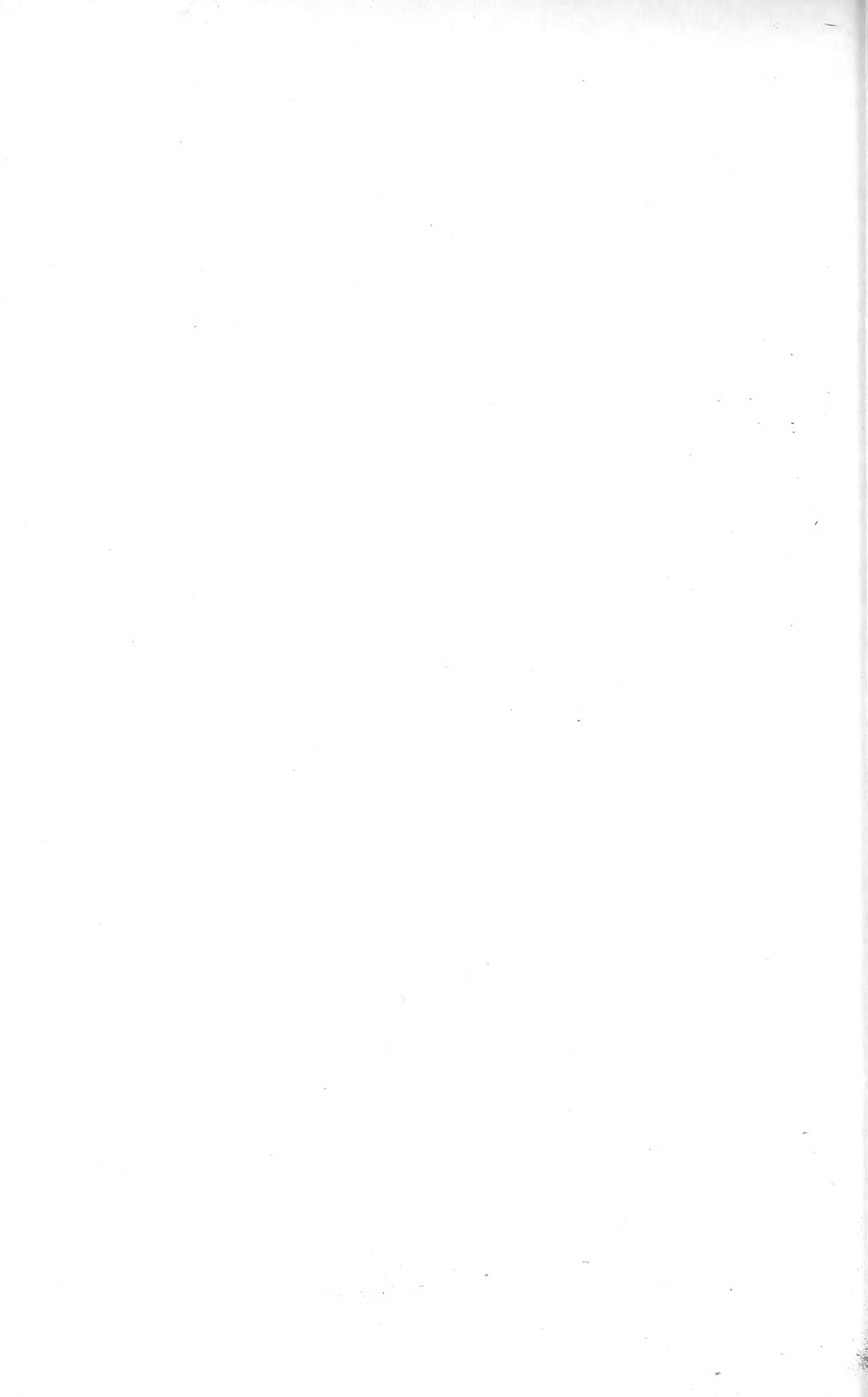




FIG. 1.



FIG. 2.

A STUDY OF YOUNG SAILFISH (ISTIOPHORUS).



FIG. 3.

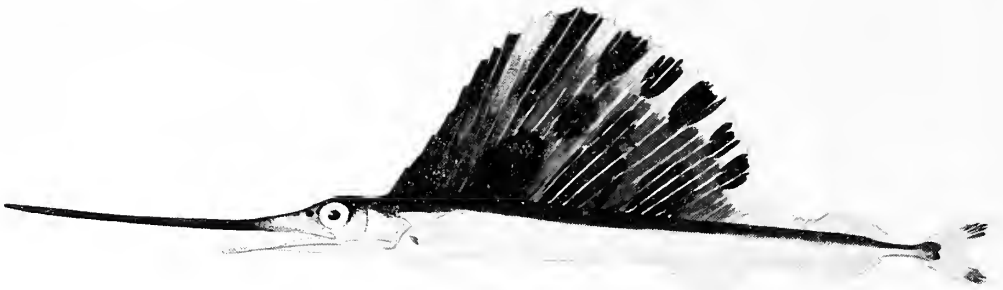


FIG. 4.

A STUDY OF YOUNG SAILFISH (ISTIOPHORUS).

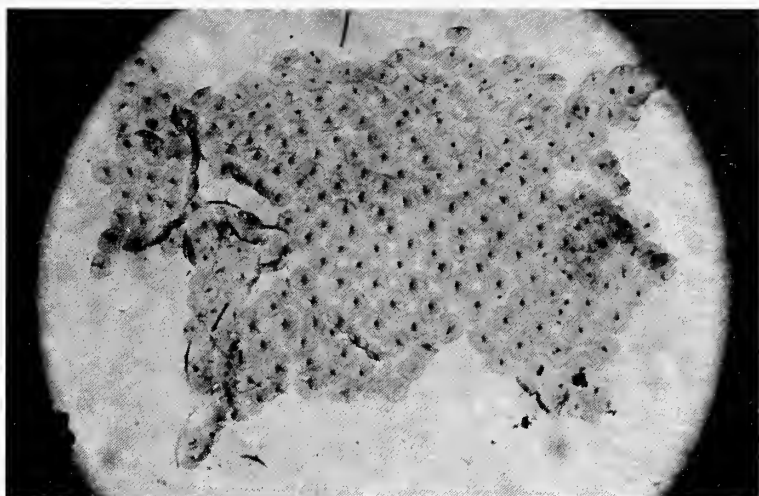


FIG. 5.

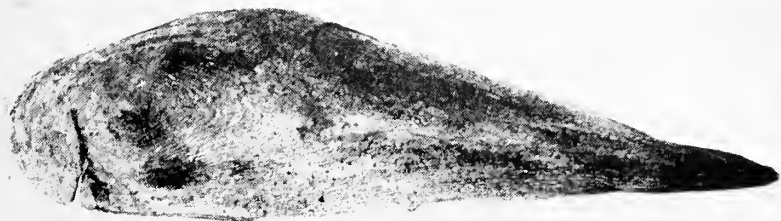


FIG. 6.

A STUDY OF YOUNG SAILFISH (ISTIOPHORUS).

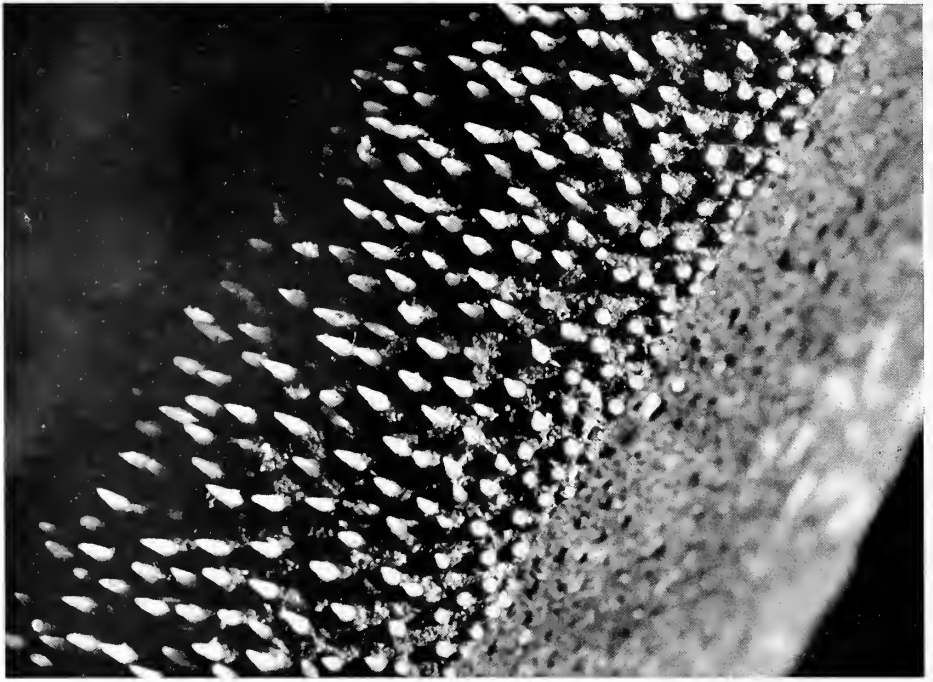


FIG. 7.



FIG. 8.

A STUDY OF YOUNG SAILFISH (ISTIOPHORUS).



FIG. 9.

A STUDY OF YOUNG SAILFISH (ISTIOPHORUS).

21.

On the Reproduction of *Opsanus beta* Goode & Bean.

CHARLES M. BREDER, JR.

New York Aquarium.

(Plates I and II).

INTRODUCTION.

The species of toadfish, *Opsanus beta* Goode & Bean, formerly synonymized with *Opsanus tau* (Linnaeus) by most authors but reestablished by Schultz & Reid (1937), has not been studied from a standpoint of its reproductive habits. This form of *Opsanus* abounds in the vicinity of the field station of the New York Aquarium located on Palmetto Key in Charlotte Harbor on the west coast of Florida. In making the studies on the reproductive habits of *Paraclinus marmoratus* (Steindachner), Breder (1939 and 1941), it was encountered on its nests in considerable numbers, especially in Pelican Bay where most of the *Paraclinus* work was carried on. The observations and studies discussed herein were made during 1939, January 25 to February 21, and May 17 to May 31; 1940, June 17 to July 8; and 1941, March 4 to April 1, incidental to other more pressing problems. In 1940 Dr. Louis A. Krumholz acted as assistant at the laboratory, while at the other visits Mr. Marshall B. Bishop acted in that capacity. To both these gentlemen my thanks are due as they made it possible for much more to be accomplished than could have been undertaken without their help.

THE SPAWNING SEASON.

Nests of eggs of this species may be found only during the early part of the year. The earliest and latest dates on which nests were found, together with the respective water temperatures, are given below.

Dates	Water Temperature
March 9, 1941	67° F.
March 19, 1941	62° F.

During the period of these studies the mean midday water temperature was 67° F. with extremes of 72° and 59°.

Mr. Bishop reported seeing nests in February, 1939, so it may be inferred that the spawning season roughly covers the months of February and March. At times later than the latter month no nests were found and fish that were examined all showed a spent condition, while fishes taken in January and February were ripe.

LOCATION OF NESTS.

The nests were found located in a variety of cavities. The bottom of Pelican Bay presents a choice selection of cavities of many sorts, for most part of natural origin. Nests studied in 1941 showed the following selections of locations:

Old conch shells	2 nests
Yellow sponge cavities	2 nests
Large tin can (lard container)	2 nests
Large clam shell (<i>Venus</i>)	1 nest

Tin cans and similar human trash is very rare in this region, but it will be noted that nevertheless two fishes selected such sites. Incidentally it was a single can, one nest inside and one outside. The other three types of items are apparently the most common objects presenting suitable cavities in the area and doubtless represent the primordial nesting cavities of this species. *Opsanus tau* in the vicinity of New York City nests almost exclusively in cavities presented by human artifacts but here such places are common while large shells and other suitable natural cavities are comparatively rare.

SIZE OF EGGS.

The large eggs are almost indistinguishable in general appearance from those of *Opsanus tau*, as might be expected. Twelve such eggs carefully measured showed the following diameters and numbers:

Diameter in mm.	Number of eggs
3.9	3
4.0	2
4.1	5
4.2	0
4.3	1
4.4	1
Mean Diameter	4.1
Maximum	4.4
Minimum	3.9

As there frequently is distortion of the eggs due to the pressure of adjacent ones, care was exercised in making the above measurements to include only eggs which could be seen to be perfectly spherical except for their point of attachment. According to Gudger (1910) the eggs

of *Opsanus tau* average 5 mm. in diameter, making them nearly a full millimeter larger than those of *Opsanus beta*.

PARENTAL BEHAVIOR.

While *Opsanus tau* is reported by Gudger (1910) to show some parental instinct in both sexes, only males have been noted with eggs in *Opsanus beta*. But then, the present author has seen only males with eggs in the former species. In order to obtain better understanding than could be had in the field on the attitude of these fishes toward their eggs, some were established in laboratory aquaria. Details of two of the most interesting are given below.

A nest in a large conch shell, *Busycon perversum* (Linnaeus), was obtained on March 9 and maintained in an aquarium until March 22 in standing but frequently changed water. The attendant male measured 130 mm. in standard length and represents a fair average size for the species in this region. As set up in the aquarium it is shown in a typical pose in Plate I, Figure 1. Usually the tail of the fish was thrust into the spiral whorl of the shell and when frightened it could back further into it until nearly out of sight, but when disturbed it was more apt to attack than to retire. While in the posture shown the right pectoral fin would be fanned back and forth over the eggs with greater or less vigor. When the fin was agitated rapidly even large particles of foreign matter would be moved from the eggs.

At intervals of a half hour or so the fish would usually shift its position to the other side of the opening and use the left pectoral for a while, as shown in Plate I, Figure 2. This position was not used nearly as much as the former. Incidentally the diagnostic pattern on the pectorals of this species may be clearly seen in these two photographs. The eggs formed a uniform single layer in the shell cavity and, as may be seen in the first photograph, reached far back into the shell. The spawning activity would seem to have taken place with considerable flurry for as may be seen, especially in the second photograph, two eggs are attached to the "roof" of the cavity. The shell is not in the position in which it was originally found, having formerly rested on the upper forward part. This may be noted by the lack of living growth of invertebrates and whitish color of the part on which it originally rested. In this position there could have been only a small crack between the lip of the shell and the sea floor. Presumably the nesting fish had excavated a passage for itself between the shell and the sand. Thus, the incubating fish, on transfer to the aquarium, was forced to adjust itself to the new position in which it found the eggs. Originally it must have done its incubating in a nearly inverted position. Actually most, but not all, of the nests of this species and of *Opsanus tau* seen by the writer have the eggs on the under surface of some protecting object. Consequently the two stray eggs must have fallen to their present position rather than have been knocked

upwards. Spawning in an inverted position with such large, heavy eggs, it is rather strange that more do not fall to the bottom, and it may be that the violence of the parents' activity serve to keep them knocked about and upwards until they adhere to a solid surface.

The activity in this nest was greatest at night and the relatively great amount of light in the aquarium seemed to discourage incubating. Darkening the aquarium would usually induce a resumption of activity. On the second day the fish had excavated a place for itself under the shell in which it spent most of the time, coming out at intervals to fan the eggs. At times it would fan a pectoral in its retreat cavity similar to that activity over the eggs. It is not clear whether this was due to a confusion and the activity was merely instinctive to a brooding fish or whether they may sometimes normally circulate water about themselves for other than brooding reasons. At least, other non-brooding specimens have not been noted to behave in this manner. All food was refused by the fish during this period of observation, although a variety of living fishes and small crabs were present in the aquarium. Due to a cold snap in which the temperature in the laboratory aquaria dropped to 69° F, all the eggs of this and other species died. The fish continued as before to incubate them spasmodically and only when they had turned black and began to foul the water from decomposition was the matter terminated.

The eggs of two nests found on a large tin can were taken without the attendant parents and carried on in the laboratory without parental attention. The parts of the can to which they were attached were cut out. The only attention these eggs received was an occasional shaking to remove the settling sediment as noticed. They seemed to be developing as well as those with a parent and, like those, were lost due to low temperature.

Another nest with an attendant parent was found in the cavity under a living sponge, *Verongia fistularis* (Pallas), on March 19, 1941. The parent here was much smaller, 95 mm. in standard length. The eggs were on the roof of the cavity and when transferred to an aquarium the sponge was only tipped slightly so that the fish might be seen in as near its normal position as possible. Plate II, Figure 3, shows this with the fish in its inverted position. The activity of the fish was about like that of the former, but the nest could not be retained as long because of the death of the sponge and subsequent fouling of the aquarium. This nest in an inverted position is shown in Plate II, Figure 4. The eggs, new and still clear and nearly the color of the yellow sponge, may be seen clinging to the irregular cavity mostly as highlights reflect from their upper surfaces. This was a very small clutch of eggs, as were many of those found. None were taken with evidences of more than one laying nor were the quantities such as to demand the products of more than one female. Gudger (1910) found both too many eggs for one female and

eggs in several stages of development in his study of *Opsanus tau* on the North Carolina coast.

DISCUSSION.

It is evident from the preceding data and the work of others on the more northern species that there is at least as much similarity between the spawning activities of these two fishes as there is between their physical attributes. The differences noted would seem to be incidental and due to environmental circumstances rather than specific attributes. For example, the finding of an apparently monogamous habit as compared with a polygamous one would seem to be referable to conditions of the bottom, number of available nesting sites and the consequent chances of success on the part of the males in their efforts. In this region suitable nesting cavities are ubiquitous and there is presumably less competition, crowding and resulting fighting for them than in localities where the competition is keen and a larger percentage of fish are doomed to be unsuccessful bachelors.

The smaller egg size seems to be a real and significant difference but the other details are in substantial agreement, even to the temperature of the water at which reproduction takes place. One noteworthy element in this connection is that in the northern form reproduction takes place when the water reaches its approximate maximum temperature whereas in the southern form reproduction takes place when it reaches its approximate minimum. The eggs incidentally are incubated close to their lower threshold of temperature, although the adults survive much lower temperatures. While the temperatures given by Parr (1935) for the Atlantic coast are not directly referable to the distinctly heterothermy conditions under which *Opsanus* lives, his temperature trends of surface waters bear out this as a general condition. Bigelow & Welsh (1925) give June and early July as the spawning season in Massachusetts, during which time the surface temperature is between 60° and 70° F.

Nichols & Breder (1926) record 67° as a spawning temperature and give June and July as the spawning months in the vicinity of New York City. Hildebrand & Schroeder (1928) found females in a ripe condition from April to October in Chesapeake Bay. Those taken in the later months would almost surely be expected to carry over to the next spring. In connection with dates north and south of this region, June, July and perhaps August would seem to be the months in which actually to expect nesting to take place in this region. Gudger (1910) found nests during these three months at Beaufort, North Carolina, during which time the temperatures reached as high as 81°. It thus appears that these fish spawn for the most part in water in the middle and high sixties extending, where the temperature rise is rapid, into the seventies or even the low eighties.

Goode (1884) quotes Silas Stearns as giving

April and May as the spawning time in the Gulf of Mexico. These observations presumably were made at Pensacola. It is not clear whether what we here understand as *O. beta* is referred to or whether the fish were *O. pardus* Goode & Bean. In either case the cooler water about Pensacola as compared to the shallow and easily warmed Charlotte Harbor might well account for the difference in time.

Small specimens are not especially abundant in the winter but one measuring 33 mm. in standard length was taken on March 20, 1941. It would seem to be a stunted specimen from the year previous rather than a precocious individual of the current season. Specimens down to about 60 mm. are not uncommon and seem to be referable to the previous spawning period. Above approximately 90 mm. they are all sexually mature. Since the spawning season is evidently quite short it is inferred that this spread in sizes and lack of distinct year classes is referable to the large variety of environments and fluctuating temperatures in which they are found. Both very local vagaries in temperature and available food could make for large differences in the growth rates.

SUMMARY.

1. *Opsanus beta* spawns on the Florida west coast in February and March in a water temperature of about 67° F.
2. Nesting sites are similar to those of *Opsanus tau*, as are the chief features of its reproductive habits.
3. The eggs average 4.1 – mm. in diameter and are found in clutches, guarded by a male, which are apparently the product of a single female.
4. Both species spawn under about the same temperature although in the north this is approximately the highest temperature reached and in the south the lowest, making the two species respectively summer and winter spawners.

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EXPLANATION OF THE PLATES.

PLATE I.

- Fig. 1. Brooding male aerating its eggs with one pectoral. This was the most generally used position of this specimen.
 Fig. 2. Alternate position of the above fish employing the other pectoral. This position was much less frequent.

PLATE II.

- Fig. 3. Brooding male with its eggs in a sponge cavity, showing the inverted position.
 Fig. 4. Detail of above nest, showing eggs attached to under surface of sponge.

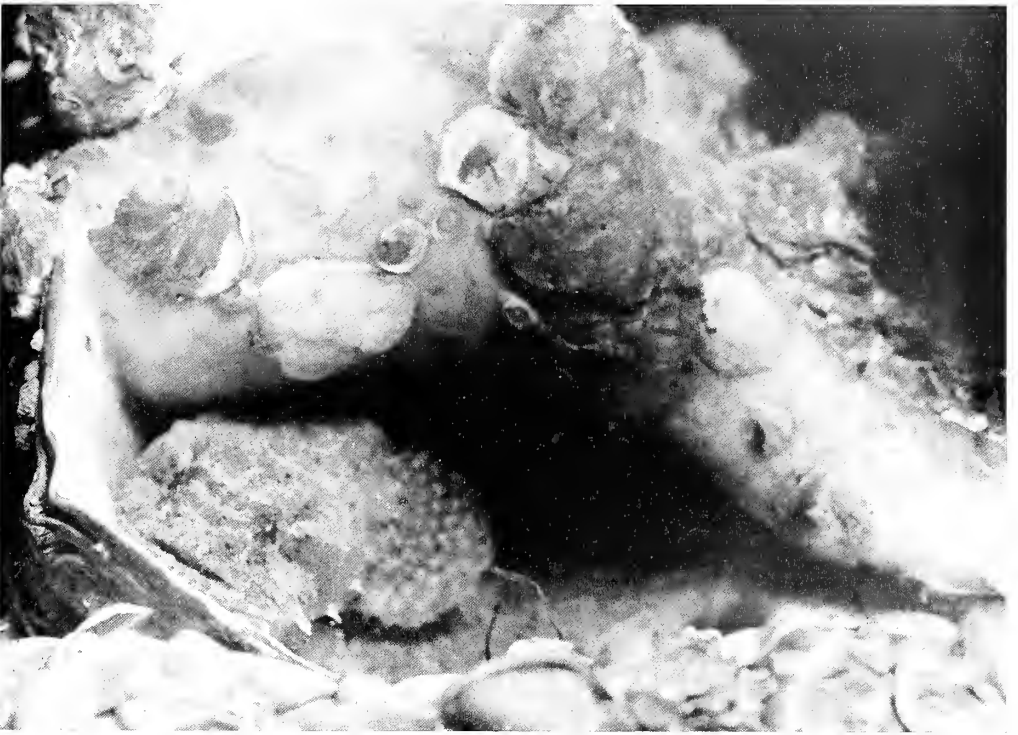


FIG. 1.



FIG. 2.

ON THE REPRODUCTION OF OPSANUS BETA GOODE & BEAN



FIG. 3.



FIG. 4.

ON THE REPRODUCTION OF OPSANUS BETA GOODE & BEAN

22.

On the Reproductive Behavior of the Sponge Blenny, *Paraclinus marmoratus* (Steindachner).

CHARLES M. BREDER, JR.

New York Aquarium

(Plates I-III; Text-figure 1).

INTRODUCTION.

Studies on the life history and development of the sponge blenny, *Paraclinus marmoratus* (Steindachner), Breder (1939), have been followed in March, 1941, by studies on reproductive behavior. The material was obtained from the same locality, Pelican Bay, and the work carried on at the research station of the New York Aquarium, located at Palmetto Key, Florida. Again, Mr. M. B. Bishop of the Peabody Museum, Yale University, was of aid in the collecting activities.

LOCATION OF NESTS.

During the winter of 1939-1940 a heavy freeze in this area, coupled with the presence of a large amount of cold water, caused a heavy mortality in the local fish population. It evidently changed the nature of the bottom invertebrate fauna to a considerable extent and *Paraclinus* was not as numerous as the year preceding the freeze. The observations were made a month later than those on which the first paper was based. Nevertheless, due to annual variations, the mean water temperature for March was lower, 67° as against 70° for February, 1939. It was first thought that the height of the spawning season had passed, although this was subsequently found to be untrue. Actually, most of the local population of *Paraclinus* was to be found along the northwest shore of Palmetto Key in beds of eel grass and in a ripe or nearly ripe state. It may be that they were just moving into Pelican Bay because of a thermal delay or that they had changed their center of abundance to some extent. In any event, nests were found only in Pelican Bay and were only two in number. One was built in a bed of filamentous algae, a new site for such nests, and the other in a cavity at the base of a sponge, *Verongia fistularis* (Pallas), of the type with which these fish are often associated. In this case the male was obtained with the nest of eggs. All were transferred intact to an aquarium. The

observations of behavior are based on the activity of this fish and three females placed in the same aquarium.

PARENTAL CARE.

As soon as the nest under discussion was placed in an aquarium, the male took up a position immediately under the eggs, as shown in Pl. I, Fig. 1. Almost at once he started working over the eggs. Every so often he would take a small part of the cluster in his mouth and pull on it. He was first thought to be eating the eggs, but it was soon seen to be some sort of fluffing process which loosened the entire mass. Alternating with this process the male would nestle under the eggs and violently agitate the cluster with one pectoral fin, then slightly rolling over would agitate the mass from the other side with the other pectoral fin, and occasionally would use both at once. This action was very violent, the fish bracing itself solidly with its ventral fins and the expanded tail during these movements. The action is as violent on the stringy mass of eggs as that undertaken by an *Ameiurus* on its eggs. Apparently vigorous agitation is necessary for the development of such agglutinated eggs. At least, it is difficult to hatch either in standing water.

The attending fish was extremely busy, twisting, turning and occasionally coiling itself around the eggs and poking at them with its mouth from all possible angles.

At times the fish would back out of the nest and take hold of the edge of the egg mass and pull it out while energetically shaking it. This is shown in Pl. I, Fig. 2. All these acts seem to insure aeration to the most centrally located eggs. Less frequently it would back well out of the nest area and pull on the egg mass until the entangling fibers were drawn out into long threads as shown in Pl. II, Fig. 3. When the eggs were released these fibers would spring back and return the attached eggs to approximately their former positions.

This type of activity continued for the duration of the observations.

SPAWNING.

On this same day, March 13, three females were added to the aquarium. As soon as they became composed they began to explore their surroundings. The largest, with her abdomen bulging, approached the nest and its guarding male. Although the male was quite dark, mostly brownish, on sighting the approaching female he put on an intense purple coloration which was nearly black and dotted with brilliant metallic blue. Contrasted to this, the female was very light, almost white, with tan markings. After some hesitancy and a few false starts, she entered the nest without much ceremony while the male vibrated his body briskly. He came half out of the nest hole and she, twisting to an inverted position, slipped in beside him as shown in Pl. II, Fig. 4. In this figure her body is mostly hidden by his but the tail and after part may be seen in the lower left hand corner.

A moment later she had slipped further into the nest and he backed in with her, the female retaining her inverted position while the male remained upright. The light but characteristic markings of the female are well shown in Pl. III, Fig. 5, which is a photograph of the actual spawning operation. A single egg, attached by its thread, which had become displaced, may be seen just above the female's anal fin and below the tip of the male's jaw. At such times the bodies of both fish would vibrate violently. The pair seemed to have spawned several times before the female withdrew from the nest in a much deflated condition. Due to the confined quarters of the small nest hole, further details of the spawning were not discernible. In any event, it is certain that a close approximation of the genital pores is not necessary in these fish. No genital papilla could be detected. The opinion expressed by Breder (1939) in regard to males spawning with a succession of females was confirmed upon further examination of the nest. This examination showed the well developed eggs in various stages with which the male was originally found, together with new eggs, fertilized in the aquarium.

This same female, about an hour later, entered the nest again and the spawning act was repeated with identical detail. While this was going on, a second female approached the nest. After the

first female had left the nest, the second, which was very similar to the first in coloration but slightly smaller and not quite so heavy, attempted to enter. However, instead of being greeted by a vibrating male, she was greeted with an open mouth and a threatening attitude. On this rebuff she backed off. On a second attempt she was more insistent and disregarded his threatening attitude. This resulted in the male's biting at her and she then gave up any further attempts.

Since the male took his threatening attitude when only her head was visible to him, it is thought that he was at least temporarily exhausted and resented the approach of any other fish bent on spawning or egg stealing. The threatening attitude and the approach of the second female is shown in Pl. III, Fig. 6.

These observations were made in the late afternoon and by dusk he had lost his deep purple and had taken on a lighter color, especially on the sides of the body.

There were no further attempts at spawning, but the male continued to tend the eggs, with some interruption, until decomposition of the sponge, which had died, forced a conclusion to the observations.

DEVELOPMENTAL NOTES.

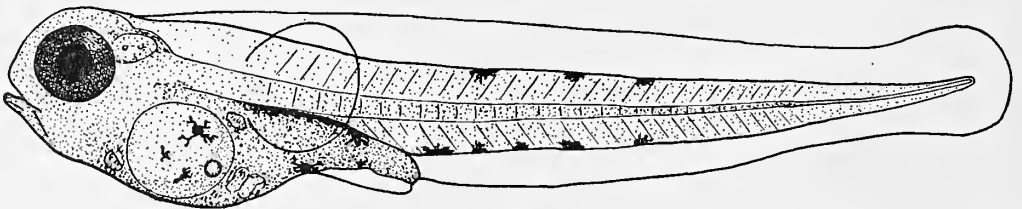
The eggs from the nest in filamentous algae were incubated with some difficulty. The larvae, however, were carried on to a stage a little beyond those mentioned in the earlier paper. It was noted that the oil globule in the yolk shrank rapidly and before a day of life after hatching the larvae sought the bottom of their dish and were negatively phototropic. It would seem from this that their life as planktonic elements must be exceedingly short and may in fact never be fully realized in a state of nature.

Text-fig. 1 shows a lateral view of such a larva, March 14, less than 24 hours from the hour of hatching. A sudden drop in temperature carried the water in the laboratory to 60° F. followed by death of all eggs and larvae.

DISCUSSION.

The literature on the reproductive habits of the blennies is scant but evidently *Paraclinus* is fairly typical in its reproductive behavior.

The spawning of *Clinus argentatus* Cuvier &



Text-figure 1.

Larva less than 24 hours old. At this time they seek the bottom and are negatively phototropic. See Breder (1939) for earlier stages and eggs.

Valenciennes is described by Guitel (1892 and 1893a) as taking place with the female in an inverted position. Apparently the original nest site is selected by the female, an item of behavior the present observations did not cover, but as in *Paraclinus* the guarding males will receive the product of several females. Although Guitel's description differs in detail, the general performance must be very similar. It would seem likely that the differences noted are merely incidental, and due chiefly to those associated with environmental differences, number of fishes present, et cetera. The described color changes, so far as they go, must also be closely similar.

Blennius montagu Fleming spawns with both fish in an inverted position according to Guitel (1893a and b). It would seem probable that whether only the female or both fish turn over may be incidental and subject to considerable individual variation. *Blennius sphynx* Cuvier & Valenciennes, according to the same author, behaves in an essentially similar manner.

Heterostichus rostratus Girard has thread-bearing eggs but according to Barnhart (1932) the habits must be rather different from the preceding forms.

The above four species all have eggs provided with adhesive filaments. Among those forms with eggs that are merely adhesive, the data in the literature is not sufficiently detailed to warrant a close comparison.

Of the various types of fishes which produce eggs with adhesive filaments, generally attached to the underside of some object, the present case seems to be the first notice of a fluffing process employed by the attendant male. The nature of the fibrous tangle in which the eggs are found makes such a process possible. In such forms as *Monocirrhus polyacanthus* in which each egg hangs separately by a single thread, no such behavior was noted by Coates (1933). In others, such as some of the Exocoetidae, Belonidae, Cyprinodontidae and Atherinidae, there is no parental care accompanying the production of thread-bearing eggs.

SUMMARY.

1. The male *Paraclinus marmoratus* guards and tends its eggs, a prominent feature of the care being that at intervals the tangled clump of thread-bearing eggs is pulled open and fluffed.
2. Wandering females are received by the male, adding their eggs to those already present and spawning in an inverted position while the male remains upright.
3. The nesting male on exhaustion will repulse additional females with the typical warning attitude or eventual biting.
4. The larvae, which float on hatching, seek the bottom within a day and are thus a planktonic element for only a very brief time.

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EXPLANATION OF THE PLATES.

PLATE I.

- Fig. 1. Male *Paraclinus marmoratus* standing guard under its eggs in a basal cavity of a sponge. *Verongia fistularis*. This photograph and those following are all of one male, showing various activities incident to reproduction.
- Fig. 2. The male tugging at the thread-bearing egg mass. This activity apparently insures aeration of the entire cluster.

PLATE II.

- Fig. 3. Sometimes long strands would be pulled far out, as here shown. A moment after this photograph was taken the fish relinquished its hold and the resilient threads snapped back into place.

- Fig. 4. A female entering the nest. She is in an inverted position, her tail showing in the lower left hand corner, while the male, who has half left the nest with fins wide spread, hides her anterior parts.

PLATE III.

- Fig. 5. The actual spawning process. Note that the female is in a very light color phase and the male very dark. A single dislodged egg may be seen above the anal fin of the female and below the tip of the male's jaw.
- Fig. 6. Another female approaches immediately after the preceding spawning and is greeted by the typical threatening attitude.



FIG. 1.

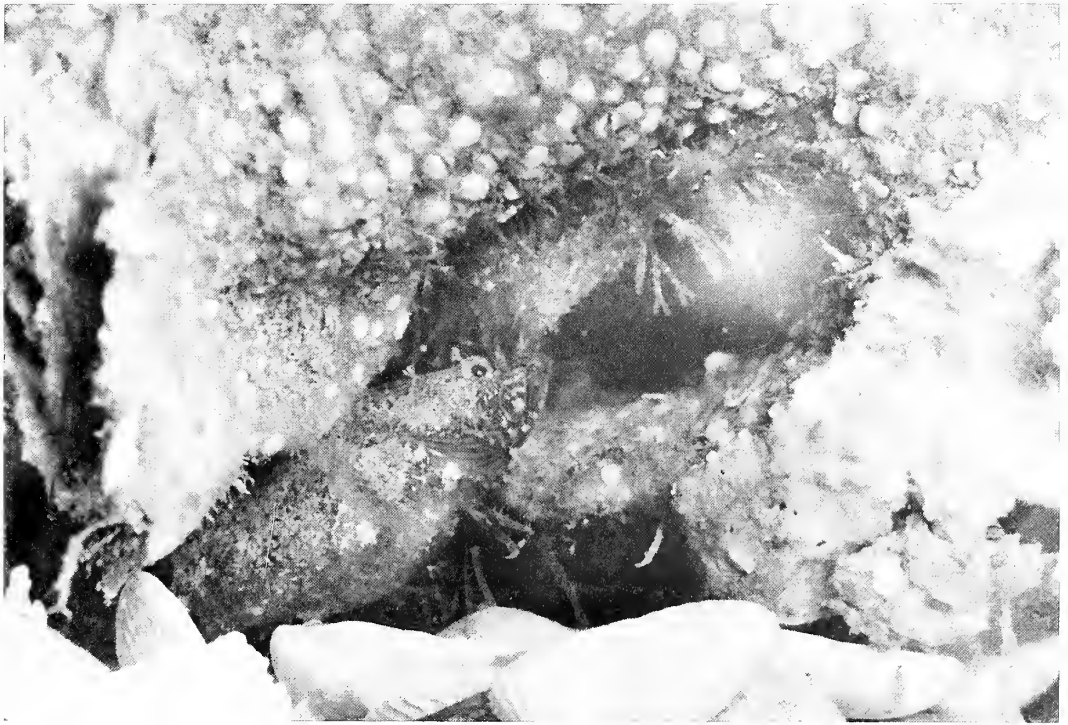


FIG. 2.

ON THE REPRODUCTIVE BEHAVIOR OF THE SPONGE BLENNY,
PARACLINUS MARMORATUS (STEINDACHNER).



FIG. 3.



FIG. 4.

ON THE REPRODUCTIVE BEHAVIOR OF THE SPONGE BLENNY,
PARACLINUS MARMORATUS (STEINDACHNER).

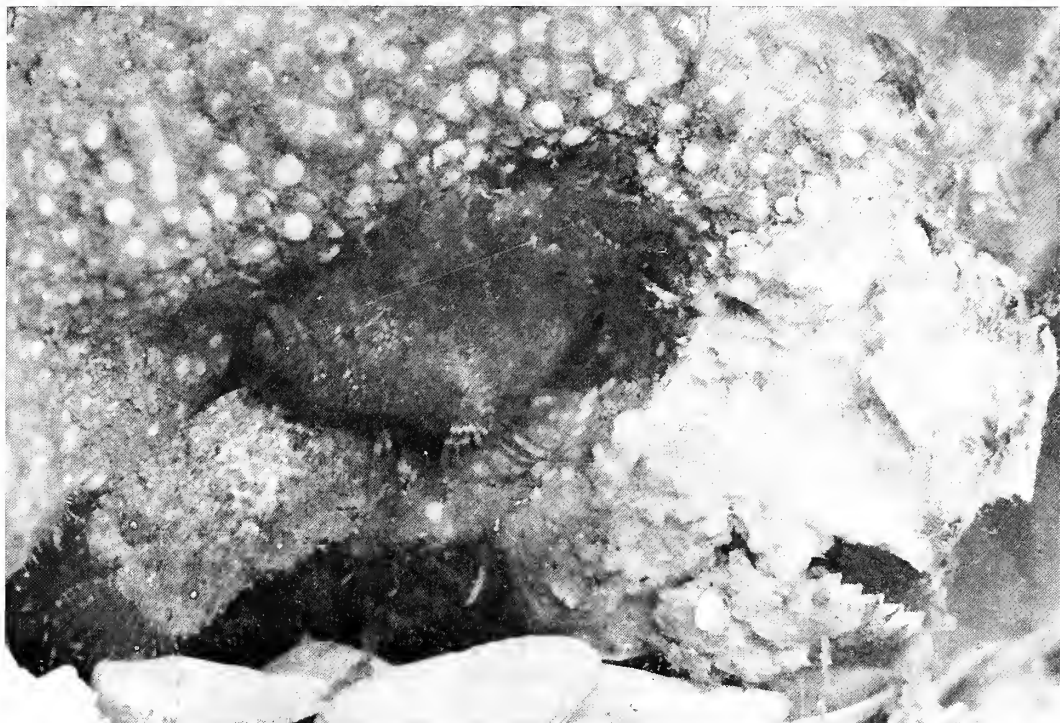


FIG. 5.



FIG. 6.

ON THE REPRODUCTIVE BEHAVIOR OF THE SPONGE BLENNY,
PARACLINUS MARMORATUS (STEINDACHNER).



23.

The Chromatophores of *Fundulus heteroclitus* in Polarized Light.

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New York Aquarium.

(Plates I-III).

INTRODUCTION.

It has been shown by several investigators that certain tissues and many cytological structures having a high degree of organization will show the phenomenon of birefringence (see Schmitt, 1940, and Fischer, 1941). The possibility that chromatophores may be a modified form of muscle as indicated by Spaeth (1916) suggested the use of polarized light for this study. By this means we have found doubly refracting material to be definitely associated with pigment cells on the scales of *Fundulus heteroclitus*. Our observations on this phenomenon are the subject of this paper.

PROCEDURE.

The instrument employed was a Bausch and Lomb microscope fitted with apochromatic lenses. To this the Nichols prisms from a polarimeter were added. The polarizer was mounted below the substage and the analyzer above a high point ocular. The illumination was provided by a 100 watt G. E. projection lamp giving an intense point source of light. Birefringence was detected in the usual manner, that is, by the brilliance of the material when the prisms are set with their planes of polarization at right angles, in which condition the rest of the field is dark. The intensity of the light from the birefringent material was taken as an indication of the degree of double refraction.

All observations were made on the pigment cells of scales taken from the dorsal and dorso-lateral surface of *F. heteroclitus*. The scales were mounted as hanging drop preparations or on ordinary flat slides with coverslips; the latter method permitted the introduction of different

solutions as well as the study of the effect of pressure while the objects were still in focus.

OBSERVATIONS.

The appearance of chromatophores of a scale under low power in polarized light is shown in Plate I. The widespread distribution of doubly refracting material is at once apparent. Plate II shows two birefringent bodies highly magnified; the one in sharp focus clearly reveals delicate strands coming off the processes. In Plate III the same area as II is shown in ordinary transmitted light; here the birefringent masses can be seen faintly.

Examination of these objects with reflected light reveals them to be the guanophores described by Odiorne (1933). Our observations indicate that some of the centrally located iridocytes of the "melaniridosomes" described by Foster (1933, 1937) and shown in a photograph by Odiorne (1933) are the same doubly refracting material described in this paper in a highly birefringent state. We have found, too, that the doubly refracting substance shows a distinct relationship among melanophores and between xanthophores and melanophores as well. For example, under proper conditions each melanophore on a scale, whether dispersed or condensed, reveals birefringent material which sends out strands interconnecting with the birefringent material of other melanophores as well as with similar material associated with xanthophores. By careful focusing under oil, the xanthophores definitely are seen to lie within the substance showing birefringence; the same may be true for the melanophores although similar observations are prevented by the dense melanin granules.

From the start of our studies on birefringence it became obvious that this property could vary from zero to a certain maximum. Thus, scales, isolated from a fish kept in a refrigerator for several days, showed little or no sign of this condition when first observed under the microscope; within a few moments a decided network became apparent, many of its strands arising from the tips of the larger birefringent processes in the manner shown in Plate II. Closer observation revealed that the "contracted" melanophores were slowly "expanding" and that at least some of their processes containing the melanin were directed along the birefringent strands. Both the melanin processes and the birefringent strands in these cases were at the same focal level as well as similarly oriented, and no sharp line of demarcation was apparent between them. This relationship was further confirmed when pressure on the coverslip produced a succession of waves which arose at the base of a process containing melanin and continued outward along a birefringent strand. The transmission of these waves indicated two things more: (1) The birefringent and melanophore processes can have a certain rigidity and flexibility of structure and possibly a certain degree of contractility; (2) the branching network is not an illusion, for these waves can be seen to pass on to the rest of the birefringent network. The elastic return of displaced melanin granules observed by Behre (1935) confirms the first conclusion.

It was soon noticed that the magnitude of the birefringence could be intermediate to the extremes which were first observed. In this intermediate state the birefringent material showed a decided Brownian movement. Spontaneous changes in the degree of birefringence could also be seen. By watching granules obviously fixed in the surface of a birefringent process showing Brownian movement, it could be seen that their relative positions were unaltered even at the tip while this process was retracted. This would suggest a movement more to be expected of muscle fibers than of pseudopodia. The rigidity of this surface was also revealed when pressure of the coverslip caused a small, highly birefringent mass to move through one of the birefringent processes as though through a channel; this mass was followed by a cluster of melanin granules, which further indicates the close association of melanophores and these doubly refracting bodies.

It has been possible to watch other individual particles from birefringent strands which, like melanin granules, may apparently be left behind as the doubly refracting processes retract. These particles themselves are birefringent and appear to rotate, for this birefringence alternately appears and disappears with great regularity. Eventually, this apparent rotation ceases. Such behavior was demonstrated when an unusually thick connecting strand with Brownian movement gradually became thin midway until nothing but a fine thread with

these twinkling granules was evident; this thread soon disappeared from sight but the granules remained visible. The implication would be that such connecting strands may be present though undetectable even in polarized light.

The effects of adrenalin chloride (1 : 1000 and 1 : 2000 in sea water diluted to 0.1 normal) and 5% ether were examined. The former led to the disappearance of Brownian movement in the birefringent masses and to an increase in the intensity of birefringence, while the latter reduced the birefringence to the point of extinction, often without the return of Brownian movement. Both produced their effects in a matter of minutes. The action of ether could not be reversed with adrenalin. Ninety-five per cent alcohol does not cause the disappearance of birefringence intensified by adrenalin, although the less intense birefringence associated with Brownian movement may disappear. Tenth normal KCl, like adrenalin, leads to increased birefringence accompanied by the usual disappearance of Brownian movement. Return to tenth normal sea water reverses this. The action of these substances parallels their effect on melanophores; KCl and adrenalin cause the "contraction" of melanophores accompanied by a decrease in Brownian movement (Spaeth, 1916) and 5% ether has the opposite effect (Wyman, 1924).

According to Odierne (1933), when melanophores are "expanded" the guanophores are "contracted" and invisible. However, we have found that animals kept continuously on a dark background show a relative increase in the amount of birefringent material associated with the melanophores. This suggests a similarity of behavior in both melanophores and "guanophores." The identity of the effects of adrenalin and KCl with reference to Brownian movement in both structures further corroborates this conclusion.

DISCUSSION.

The presence of the birefringent material, its relationship to the chromatophores, and its behavior strongly suggest that this doubly refracting material is an integral part of chromatophores, at least for the melanophores and xanthophores on the scales of *Fundulus heteroclitus*.

Apparently we are dealing with a material which can exist in various states of solvation and molecular orientation. Complete lack of birefringence indicates a minimum of organization and a maximum of solvation while strong birefringence argues for a minimum of solvation and a maximum of orientation. Such changes are now well-known for chromosomes (Schmitt, 1940). Similar changes are attributed to muscle (Fischer, 1941).

The failure of birefringence to disappear in concentrated alcohol decreases the likelihood that lipoids are involved and strengthens the possibility that the molecules concerned are proteins as in muscle. It might be argued that orientation of the contained birefringent particles (believed by

Odiorne to be guanin) is concerned in the changes of birefringence. However, it is difficult to see how one could completely assign the present observations to changes in the orientation of these granules, especially in view of the complete disappearance of birefringence in 5% ether although the granules remain visible and in view of the ease with which the particles can be distinguished within the surface of the doubly refracting processes. Certainly the crystallizing out of guanin is not involved since in the strongly birefringent state no sign of the structure typical of guanin crystals is apparent.

If the movements of the pigment and other granules are associated with the changes in birefringence, as our observations tend to indicate, the following interpretation is possible. The various constituents of the chromatophores, such as xanthin and melanin, can form part of the structural pattern of the chromatophores. The degree of development of the pattern itself is governed by the metabolic state of the protoplasm; such substances as adrenalin, KCl, ether, etc., would lead to changes in the organization by affecting the metabolic processes. Melanin and xanthin, if associated with phosphate, carboxyl, amine, or hydroxyl groups by being part of certain complexes, would be able to combine reversibly with similar groups of the protein pattern of chromatophores. Reversible combinations of this kind can account for the observed changes in the freedom of movement of these granules. As part of collapsing or expanding chains of molecules, the granules could participate in the changes which have been described as "contraction" and "expansion" of chromatophores. This concept is in accord with the elastic return of displaced melanin granules observed by Behre (1935).

Gilson (1926) suggested that fine sheaths, which determine the shape of expanded melanophores, may extend into the tissue spaces. We have already pointed out that birefringent strands may appear and disappear without any evidence of movement of the particles within them, showing that a change in structure rather than a change associated with movement is involved. This would confirm Gilson's suggestion of preformed processes, but whether such processes are collapsed cylinders remains to be determined.

We have noted that the interconnecting strands among the chromatophores may be present all of the time and merely come into view under certain conditions. But this does not eliminate the possibility that part of the network may be formed by the outgrowth and fusion of new processes. Such behavior would be consistent with that which has been described for vertebrate smooth muscle: "Even in the adult vertebrate it is believed that smooth muscle cells may be derived from undifferentiated mesenchyme cells in connective tissues. The myoblasts become more and more elongate with development and appear still connected laterally by cytoplasmic processes" (Scott & Kendall,

1935). Furthermore, such outgrowth would provide an explanation for the migration of pigment cells beyond the boundaries of grafts demonstrated by DuShane (1935). Possibly the peripheral changes of denervated caudal bands which Parker (1936) has ascribed to "lipohumors" may also be accounted for in this way, especially since we have observed an increase in the extent and connections of birefringent material among chromatophores upon prolonged exposure to a dark background.

The staining techniques which have been employed to reveal the "nerves" running to chromatophores may, at least in part, have actually shown the birefringent strands; by virtue of their structure, these strands might be expected to coagulate into coarser fibrils as in the case of nerve axoplasm. Smooth muscle cells are also connected to each other by a substance showing a reticulum of fine fibers by silver techniques (Scott & Kendall, 1935).

SUMMARY.

1. Chromatophores on the scales of *Fundulus heteroclitus*, when examined in polarized light, are found to be intimately associated with a birefringent material.

2. This birefringent material has processes which send out strands that interconnect the chromatophores.

3. The intensity of birefringence of both processes and strands varies according to the conditions to which the fish and isolated scales have been subjected.

4. Changes in birefringence are accompanied by the appearance and disappearance of Brownian movement; the latter is more pronounced when the magnitude of birefringence is intermediate to zero and a certain maximum.

5. The strands of birefringent material appear and disappear spontaneously without any apparent movement; in addition to such changes, the larger processes also show an ability to move.

6. When visible, the birefringent strands may reveal a certain degree of rigidity and even contractility.

7. The movement of melanin granules in the melanophores appears to be intimately associated with this doubly refracting material.

8. The action of adrenalin, ether, and KCl on the birefringent material is similar to that described by various investigators for the melanophore itself.

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EXPLANATION OF THE PLATES.

PLATE I.

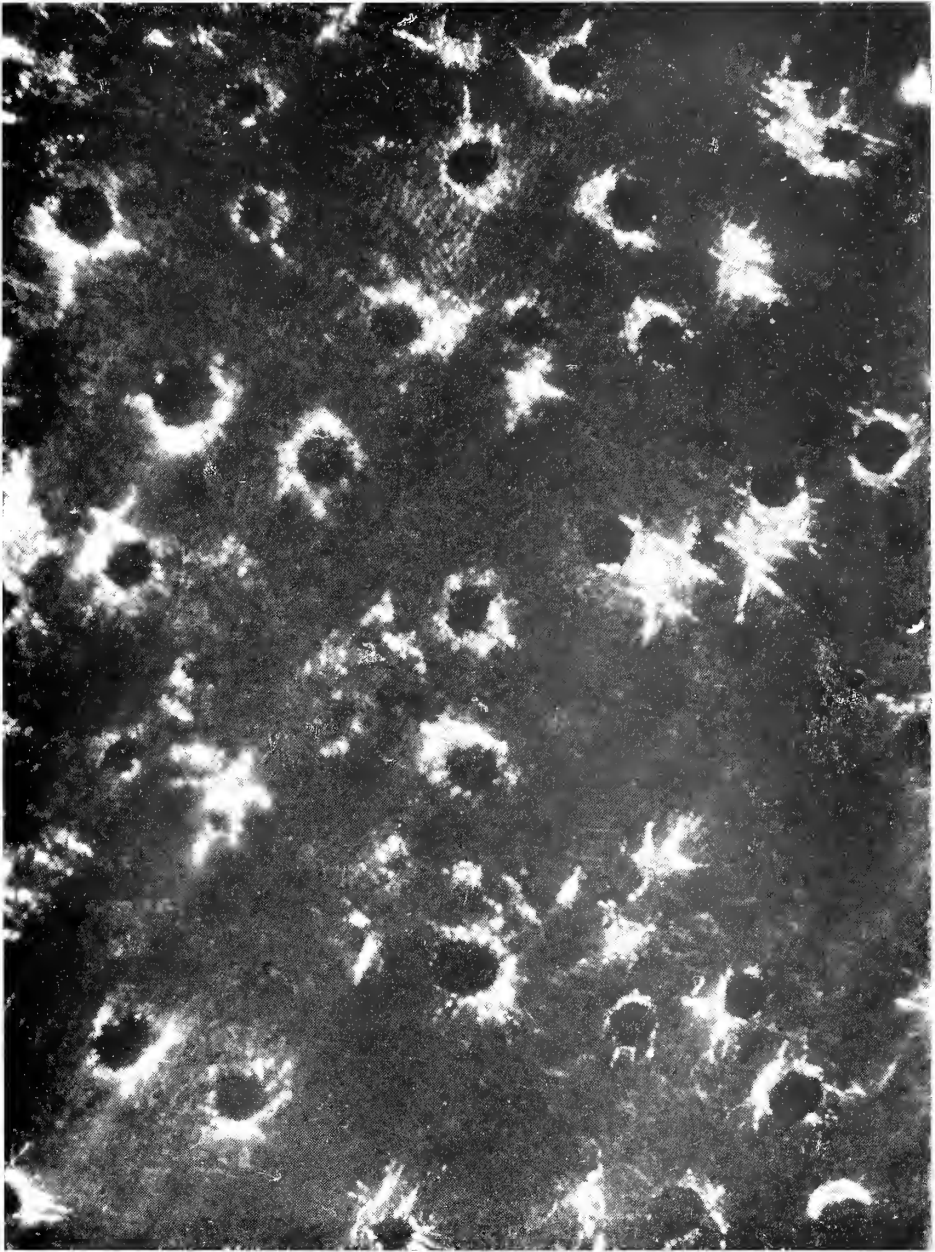
Chromatophores from the scale of *Fundulus heteroclitus* in polarized light. L. P.

PLATE II.

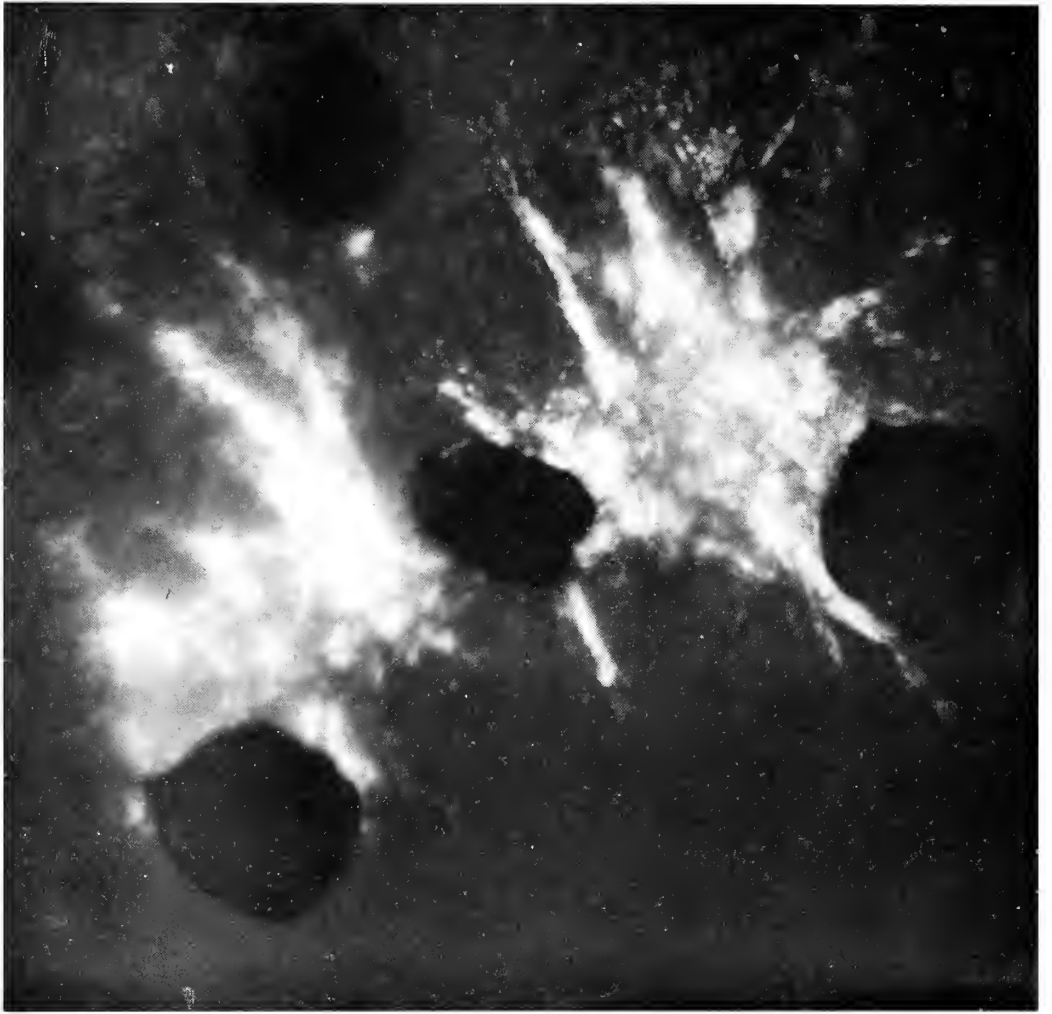
Birefringent mass associated with melanophores. Note fine strands arising from the processes. H. P.

PLATE III.

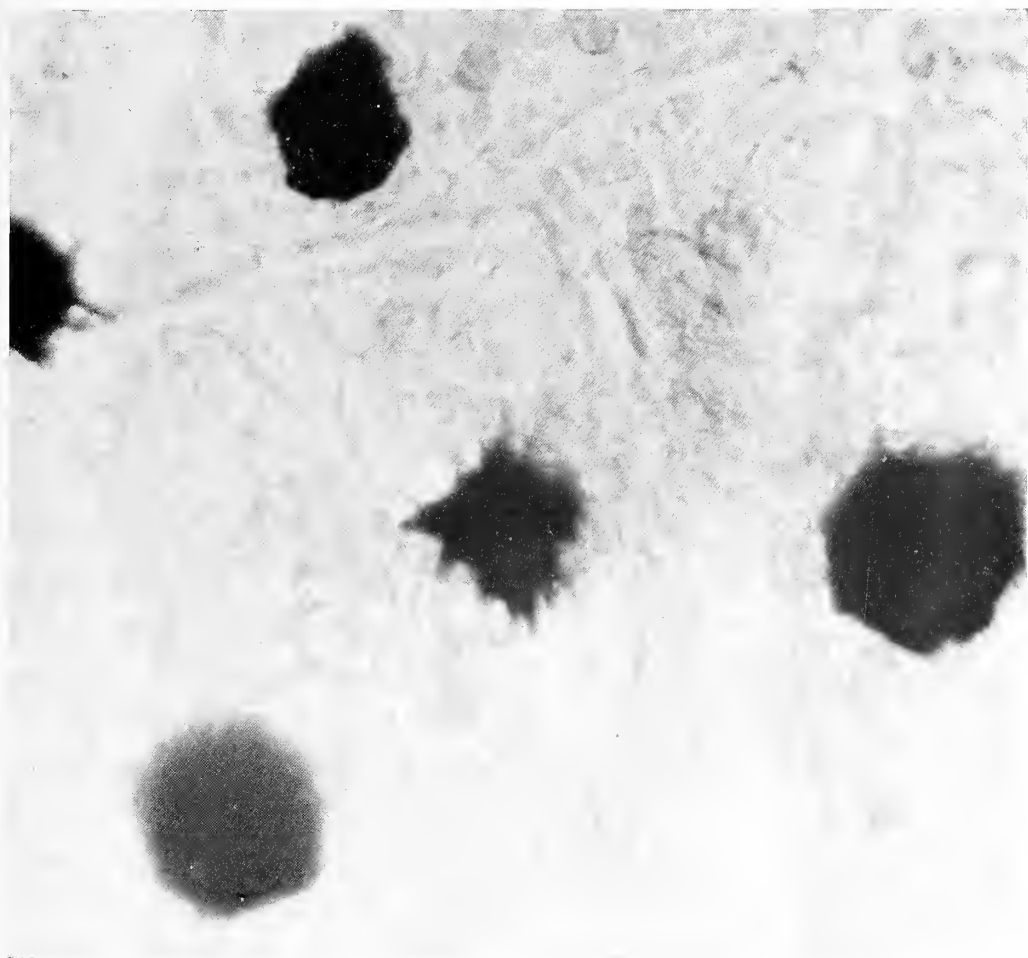
The same area as in Plate II in ordinary transmitted light. Note the faintly visible birefringent material. H. P.



THE CHROMATOPHORES OF *FUNDULUS HETEROCLITUS*
IN POLARIZED LIGHT.



THE CHROMATOPHCRES OF FUNDULUS HETEROCLITUS
IN POLARIZED LIGHT.



THE CHROMATOPHORES OF *FUNDULUS HETEROCLITUS*
IN POLARIZED LIGHT.



24.

New Races of Alaudidae and Timaliidae from Northern Thailand.

H. G. DEIGNAN.¹

Three birds, known from northern Thailand for a number of years and assumed to belong to well known races, prove, upon comparison with the related forms, to require subspecific separation. For the loan of specimens of races not represented in the collection of the U. S. National Museum, I am indebted to the authorities of the American Museum of Natural History.

I.

A form of *Mirafra assamica* is the sole member of its family yet recorded from northern Thailand. Comparison of freshly moulted examples (autumn, early winter) has shown that, while they link *assamica* (Assam) and *marionae* (Central Thailand), they are strikingly different from each and should be given a name.

The new race has the prevailing tone of the upperparts gray, as in *assamica*, not rufescent, as in *marionae*; the dark centers of the feathers of the upperparts large and well defined, as in *marionae*, not obsolescent, as in *assamica*. I propose that it be called

+ *Mirafra assamica subsessor*, subspecies nova, with the type an adult female, U. S. N. M. no. 313450, collected at Chiengmai, North Thailand, 1,000 feet, November 24, 1928, by H. M. Smith.

All but one of the northern specimens of the lark come from the Chiengmai plain, where it is very common. The exceptional example, a summer-taken bird from Ban Me Mo (in the adjacent province of Lampang), is too worn for certain subspecific identification but probably belongs with *subsector*.

II.

The population of *Garrulax chinensis* occurring throughout northern Thailand belong to a race connecting *chinensis* (Kwangtung) with *propinquus* (Tenasserim).

This form has the mantle much more olivaceous than in *propinquus* and slightly more rufescent than in *chinensis*; the gray of the pileum cut off at the lower nape and clearly defined from the olivaceous mantle, as in *propinquus*. In brief, it may be described as *chinensis* with the pileum of *propinquus*. For it, I propose the name

¹ Published with permission of the Secretary of the Smithsonian Institution.

+ *Garrulax chinensis lochmius*, subspecies nova, with the type an adult male, U. S. N. M. no. 336663, collected at Chiengsen Kao, North Thailand, January 15, 1937, by H. G. Deignan.

Of *lochmius*, I have sixteen specimens from the provinces of Me Hong Son, Chiengmai, Chiengrai, and Nan. Probably may be placed here also Salvadori's example from Yado, Karenni, which "somiglia più ad un esemplare di Hong-Kong e forse appartiene ad una forma distinta, intermedia fra la cinese e quella del Tenasserim" (*Ann. Mus. Civ. St. Nat. Genova*, ser. 3, vol. 6, 1914, p. 6).

III.

A representative of *Pomatorhinus erythrogenys*, recorded in Thailand only from Doi Chiengdao, between 4,500 and 6,800 feet, has proved to be, not *imberbis* (Karenni), as hitherto believed, but a quite different race, which may be known as

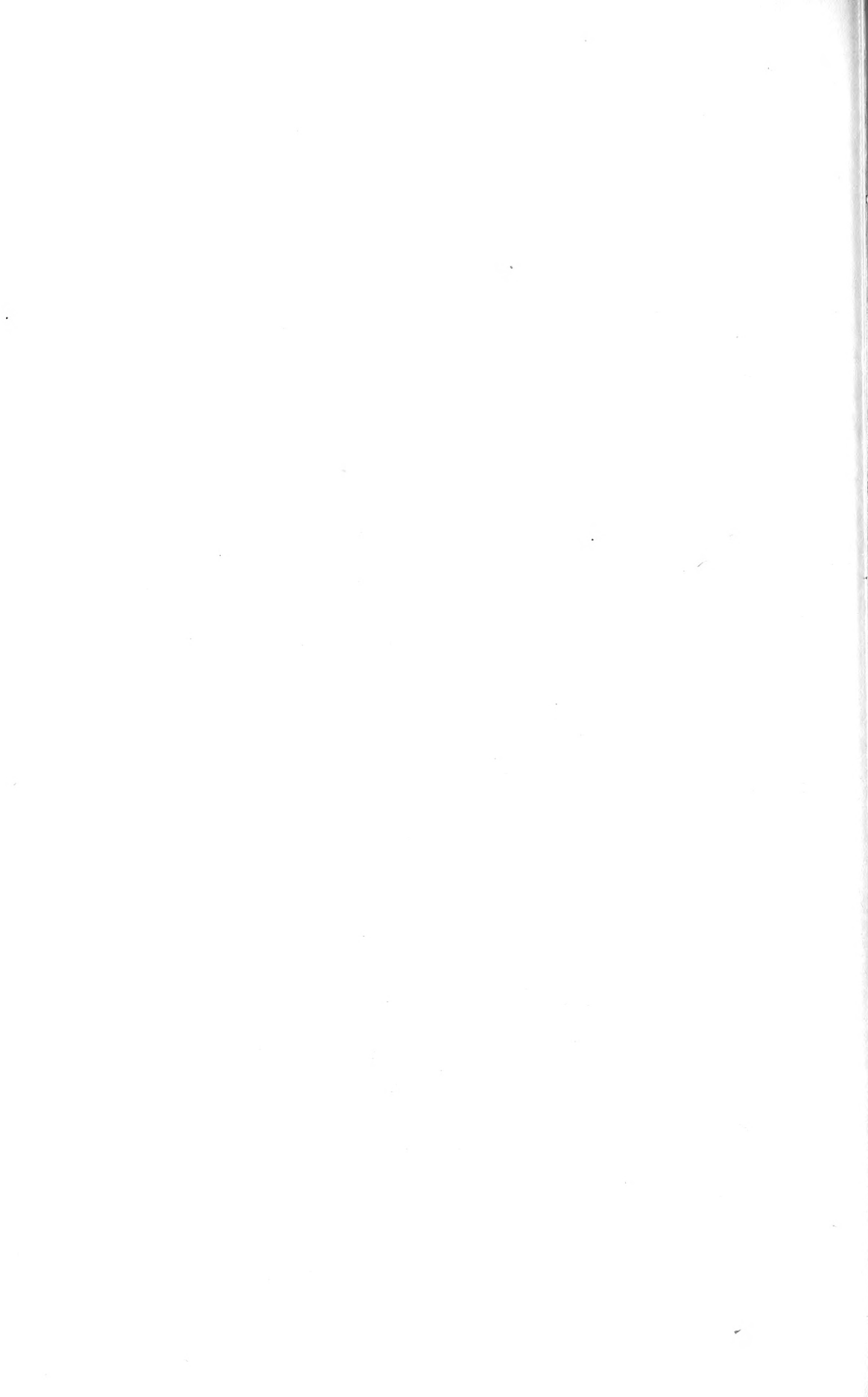
+ *Pomatorhinus erythrogenys celatus*, subspecies nova,

with the type an adult male, U. S. N. M. no. 336873, collected on Doi Chiengdao, North Thailand, March 20, 1937, by H. G. Deignan.

From *imberbis* it is readily distinguished by having the frontal feathers, sides of throat, neck, breast, and belly, the flanks, thighs, and under tail-coverts distinctly paler—orange-rufous, instead of chestnut-rufous; the feathers of the lores dark gray, not grayish-white. From *erythrogenys*, it differs in its smaller size, more vivid color along the sides of the body, and dark gray (not grayish-white) lores.

According to Stuart Baker (*Fauna Brit. India, Birds*, 2nd ed., vol. 1, 1922, pp. 220-222), all races of *erythrogenys* have the "iris light greenish white, yellowish white or pale bright yellow; legs and feet fleshy or fleshy-brown; bill yellowish-horny." The male of *celatus* has the irides red; the orbital skin plumbeous; the bill gray, with basal half dark slate; the feet, toes, and claws horny-brown.

With the new form I place skins from Kalaw and Taunggyi, in the Southern Shan States. *Imberbis* will, perhaps, like *Pomatorhinus sch. nuchalis* (a similarly saturate race), prove to be restricted to the Karen Hills.



25.

Respiratory Behavior in Fishes Not Especially Modified for Breathing Air Under Conditions of Depleted Oxygen.

CHARLES M. BREDER, JR.

New York Aquarium.

(Plate I).

Among fishes living in environments which are usually or periodically depleted of dissolved oxygen are many with specialized respiratory accessories which permit them to make use of atmospheric oxygen direct or indirectly. Fishes without equipment capable of coping with situations of depleted oxygen must perish when confronted with them unless escape is possible. When simple escape by flight is impossible, at least certain of such fishes will make attempts to seek out methods of survival which are certainly not part of the normal scheme of their activities. Two cases, indicative of such efforts at survival, seem to be rather suggestive of a point of approach to the whole problem of fish behavior in adjusting to changing environmental conditions.

One case involved a large female *Lebistes reticulatus* (Peters) in the laboratory of the New York Aquarium which was being used for some experimental work involving other matters but which incidentally concerned activities under restricted oxygen supply. In the course of this experiment small measured blocks were floated on the surface as a means of restricting gaseous interchange between the air and water. In the one referred to, the surface was nearly covered with these floats with one *Lebistes* in the water below. Following its natural response to rise to the surface and take advantage of the greater amount of oxygen near the surface film, which by virtue of peculiarly specialized mouths the Microcyprini are able to do efficiently, it found normal behavior under such conditions impossible because of the crowded floating blocks. After some little effort it managed to wriggle up between two of the blocks and bear its weight on them in such a fashion that the blocks tilted and presented a sloping surface. On this support it perched itself with only its tail immersed. Here it would rest for long periods of time, now and again submerging presumably because of the drying effects of the air. It looked very much like the normal performance of a *Periophthalmus*. This is shown in Plate I, Fig. 1. Such behavior went on for six days until the experiment was

discontinued.¹ One is forced to wonder about the origin of habits in fishes in which they voluntarily leave the water, for certainly *Lebistes* does not come out of water under normal conditions.

Some of the Microcyprini voluntarily leave the water even when there is no immediate suffocation, as anyone familiar with *Rivulus* can attest. These fish may be sometimes found flipping their way along in damp jungles, Breder (1927), or sometimes buried in the damp débris of the jungle floor. Their method of emergence and subsequent behavior is entirely different from that of *Lebistes* and apparently there is no connection between the two.

The second case involves a species of bottom fish, *Achirus lineatus* (Linnaeus). One such specimen, 46 mm. standard length, kept in a small aquarium at the Florida Field Laboratory of the New York Aquarium, was noticed performing in an unusual manner when, because of the death of some tank mates, the aquarium became foul. It would swim up to the surface and there flutter its long dorsal and anal in such a manner as to impel backwards the water above it, while in the meantime it would cup its body in such a fashion as to be fairly dish-shaped. By this action it cleared its upper concave surface of water and rested floating on the surface film by virtue of the water displaced. It is shown floating in this manner in Plate I, Fig. 2. This means of flotation was not entirely perfect, and it was forced intermittently to keep up the activity to prevent itself from sinking. By this performance, however, it apparently was able to take advantage of the greater concentration of oxygen at the surface in a manner similar to that of some of the Microcyprini with their flattened heads and upturned snouts. This fish finally succumbed after several days so it cannot be said whether its method was poor or merely

¹ Physical data on experiment (Nov. 6, 1933) Temp. 25.5° C.; Vol. H₂O 1488cc.; Surface area 3.5 C²; Free CO₂ 0.44 mM. For this experiment a mason jar was used as an aquarium. In another experiment fish died at a concentration of 0.46 mM. CO₂.

inadequate to the circumstances of this particular aquarium.

The only reference that we have been able to find with a bearing on this item is in Beebe & Tee-Van (1928). They report that this species performed in the following manner in Port-au-Prince Bay, Haiti. "On several nights I caught young soles of this species, near the surface, at our submerged light. They swam slowly along and when at the surface elevated the encircling ring of vertical fins, and depressed the body, and in this cupped shape floated with no apparent movement of fins or body. The tips of all the rays could be seen breaking the surface film, but I could see no difference in the level of the enclosed water and that outside. These specimens measured from 17.5 to 25 mm." Their fish were only about half as large as the present and were certainly under no suffocating influence where taken. It is thus evident that there is a background for this behavior in the activity of the smaller sizes. Apparently it is normally given up before the size of our specimen is reached. The present behavior then might be considered as a return to more juvenile activity on the incidence of adverse circumstances.

At the Field Laboratory many were kept under conditions far from ideal, but the present case is the only one which displayed this habit. Although submerged night lights were used continually they failed to attract this species. Most of our specimens were considerably larger than those of Beebe & Tee-Van.

The two cases mentioned are the only examples known to the writer who, because of circumstances, has had unusual opportunity both in the field and at home for a long period to note such items of behavior. How many *Lebistes* have been handled in that time would be hard to estimate but one item of behavior in this as well as related poeciliids stands out prominently. These fishes, when in pools with gently sloping edges, feed freely in very shallow water but are notably careful to avoid being "stranded." Consequently it must be assumed that the individual herewith discussed overcame this tendency in response to the greater pressure of suffocation.

During this same period several hundred achirids of various species and under varying conditions have never shown any disposition to the floating habit herein described.

Surely here is a waiting field of investigation in fish behavior, touching perhaps on the farthest reaches of the mental life of fishes. Such questions arise as to how instinctive are such acts and how widespread in an individual species.

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1928. The Fishes of Port-au-Prince Bay, Haiti, with a summary of the known species of marine fish of the Island of Haiti and Santo Domingo. *Zoologica*, 10 (1): 1-279.
- BREDER, C. M., JR.
1927. The Fishes of the Rio Chucunaque Drainage, Eastern Panama. *Bull. Amer. Mus. Nat. Hist.*, 57 (3): 97-176.

EXPLANATION OF THE PLATE.

PLATE I.

Fig. 1. *Lebistes reticulatus* resting out of water after the manner of a *Periophthalmus*.

Fig. 2. *Achirus lineatus* floating on the surface film of water depleted in oxygen.

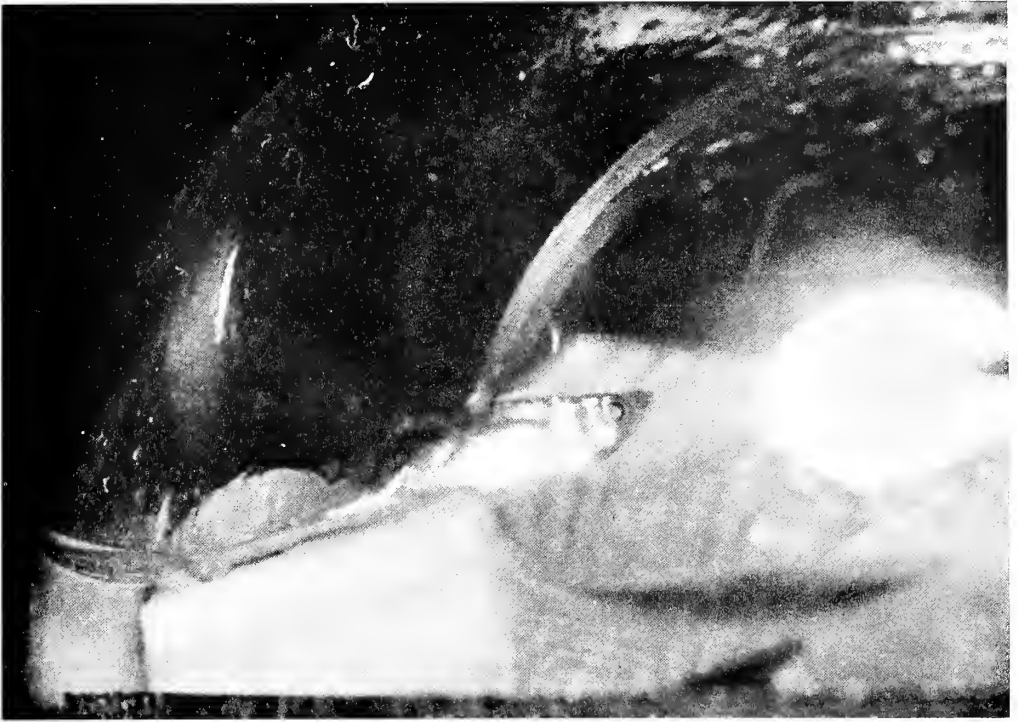


FIG 1



FIG 2

RESPIRATORY BEHAVIOR IN FISHES NOT ESPECIALLY MODIFIED FOR BREATHING AIR UNDER CONDITIONS OF DEPLETED OXYGEN.



26.

Eastern Pacific Expeditions of the New York
Zoological Society. XXVIII.

Fishes from the Tropical Eastern Pacific.

[From Cedros Island, Lower California, South to the Galápagos
Islands and Northern Peru.]Part 3. Rays, Mantas and Chimaeras.¹

WILLIAM BEEBE

&

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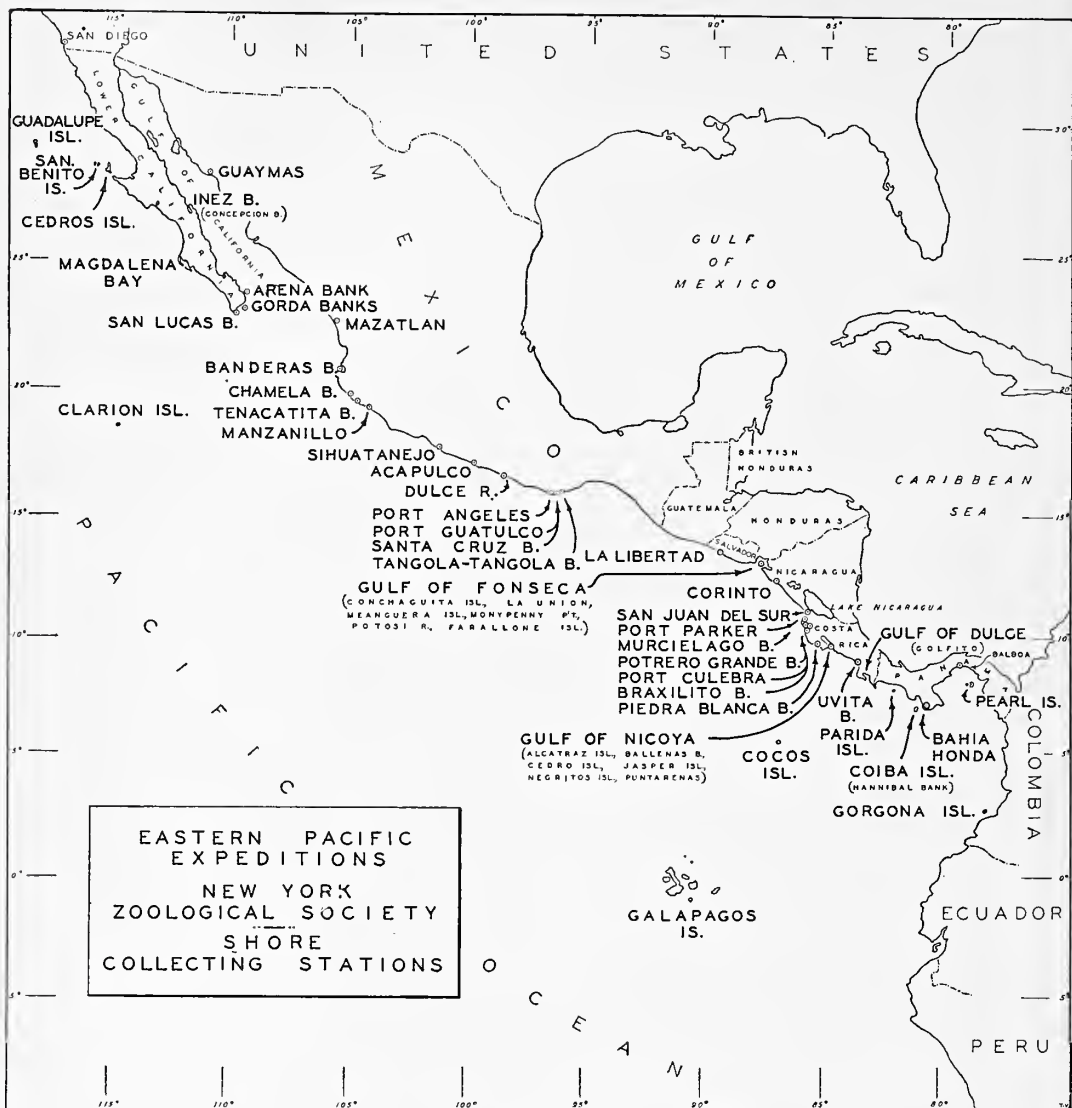
(Plates I-IV, Text-figs. 1-40).

[This is the 28th of a series of papers dealing with the collections of the Eastern Pacific Expeditions of the New York Zoological Society made under the direction of Dr. William Beebe. The present paper is concerned with specimens taken on the *Noma* Expedition (1923), the *Arclurus* Oceanographic Expedition (1925), the *Antares* Expedition (1933), the Templeton Crocker Expedition (1936), and the Eastern Pacific *Zaca* Expedition (1937-1938). For data on localities, dates, dredges, nets, etc., of the second, fourth and fifth of these expeditions, refer to *Zoologica*, Vol. VIII, No. 1: 1-45 (*Arc-lurus*), *Zoologica*, Vol. XXII: 33-46 (Templeton Crocker), and *Zoologica*, Vol. XXIII: 278-298 (Eastern Pacific *Zaca*).]

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¹ Contribution No. 630, Department of Tropical Research, New York Zoological Society.
Part 1, Lancelets and Hag-fishes, was published in *Zoologica*, Vol. XXVI, pp. 89-92; Part 2, Sharks, in *Zoologica*, Vol. XXVI, pp. 93-122.



Text-figure 1.

Principal localities in the tropical eastern Pacific where collections were made by the Department of Tropical Research of the New York Zoological Society.

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INTRODUCTION.

This paper deals with rays and mantas collected in tropical eastern Pacific waters on five expeditions of the Department of Tropical Research of the New York Zoological Society under the direction of Dr. William Beebe. As an aid to future students we have included references to all species recorded from the tropical eastern Pacific.

The geographical boundaries of the region under consideration in this paper, and which we call the "tropical eastern Pacific," are as follows: The coastal waters of North and South America from Cedros Island, off the coast of Lower California, and the Gulf of California, southward to northern Peru, including off-shore islands such as the Galápagos and Revillagigedo groups, Clipperton, Cocos and Malpelo Islands.

As far as references are concerned, we have listed the original reference with type locality, and references referring to the region under discussion. Additional references have been added, however, whenever their inclusion was felt necessary. Some of the more commonly

cited papers have been referred to by name and not by publication, serial and page numbers; the full references will be found on page 279. Synonyms of nominal forms described from the region are included, but not necessarily those from extra-limital localities.

Forty-three rays and two chimaeras are reported from the waters of the tropical eastern Pacific.

We are indebted to Miss Janet B. Wilson for inking the drawings.

KEY TO THE FAMILIES OF RAYS AND MANTAS OF THE TROPICAL EASTERN PACIFIC.

1. Snout long, slender and flat, armed with strong teeth laterally (sawfishes). *Pristidae*, p. 253
 Snout not armed with teeth laterally 2
2. Tail comparatively thick, bearing two dorsal fins; with or without a well-developed caudal fin; no serrated caudal spine. 3
 Tail slender, with one or no dorsal fins; bearing a filamentous caudal fin in the *Dasyatidae*, otherwise without a caudal fin. 5
3. Caudal fin well developed; ventral fins not notched on outer edge (do not mistake notch formed by clasper of males for a notched fin) 4
 Caudal fin absent, or represented only by a slight fold of skin; ventral fins notched on outer edge (do not mistake the notch formed by the clasper of the male for a notched fin); skin rough with scattered spines
 Rajidae, p. 254
4. Skin rough with scattered spines; electrical organs not developed. *Rhinobatidae*, p. 250
 Skin everywhere perfectly smooth; electrical organs developed. *Torpedinidae*, p. 247
5. Dorsal fins absent; eyes not at edge of head
 Dasyatidae, p. 260
 A single dorsal fin present; eyes at edge of head 6
6. Head with a pair of horn-like arms projecting forward. *Mobulidae*, p. 273
 No horn-like arms projecting forward. 7
7. Snout bilobed. *Rhinopteridae*, p. 273
 Snout single lobed. *Aetobatidae*, p. 271

FAMILY TORPEDINIDAE.

Key to tropical eastern Pacific genera.

- 1a. Pelvic fins distinct from body posteriorly, not joined together to form a disk. *Narcine*.
- 1b. Pelvic fins united to body along their entire length, joined together to form a disk
 Discopyge.

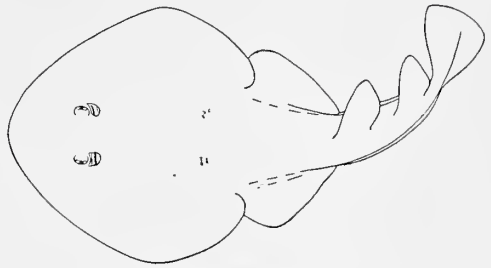
Narcine Henle, 1834.

Key to tropical eastern Pacific species.

- 1a. Disk with a single large ocellus in the center.
 omnata.
- 1b. No ocellus in center of disk.
 - 2a. Disk with a few inconspicuous rings in the young, becoming uniform in color in the adult. *entemedor*.
 - 2b. Disk with numerous white vermiculations.
 vermiculatus.

Narcine entemedor Jordan & Starks.

Ocellated Electric Ray.



Text-figure 2.

Range: Gulf of California to Panama (Mexico: San Felipe Bay, Gonzaga Bay, San Francisquito Bay, Mulege, Ballenas Bay, Carmen Island, Agua Verde Bay and La Paz, all in the Gulf of California, Mazatlan; Costa Rica: Gulf of Nicoya; Panama: Panama Bay).

Field Characters: Tail thick with two dorsals and a caudal fin well developed; pelvics not notched on outer edge; skin smooth everywhere. The ray is provided with electric organs which generate sufficient power for adequate protection. Pelvic fins separate. Young with several faint ocelli, disappearing in adult. (Illustration from Specimen 24,996; 385 mm.)

Color: The adult is uniform putty brown with indistinct spots of dusky on the body, both dorsals and caudal fin. In young individuals there are about four pairs of large ocelli on the upper surface, dark-centered with a pale outer ring of yellowish-tan. These markings fade with age so that in some specimens they are almost or quite absent.

Size: The largest recorded specimen is 762 mm. in length.

Local Distribution: We took this species only in Inez Bay, on the west coast of the Gulf of California. In mid-April they were found in shallow water at night.

Abundance: Records in literature are of single specimens, except at La Paz where they were said to be common. We found them abundant at night in Inez Bay.

Food: Specimen No. 25,249 had in its stomach a pure culture of red polychaete worms, armed with strong spicules. No. 24,996 had eaten six polychaete worms and one ascidian.

Study Material: 13 specimens. Mexico: Inez Bay; 12 rays seen, 6 collected (24,996, 25,235, 25,249); Photo. 7565; length 330 to 385 mm., April 13 to 16, 1936. Speared at night in shallow water in the southern part of Inez Bay.

References: *Narcine entemedor*, Jordan, D. S., Fishes of Sinaloa, 1895: 387, 508 (original description, color; type locality, Mazatlan, Mexico; La Paz). Gilbert, C. H., & Starks, E. C., Fishes of Panama Bay, 1904: 15, 207 (description, Gulf of California, Panama). Osburn, R. C., & Nichols, J. T., *Bull. Amer. Mus. Nat. Hist.*, 35,

1916: 144 (Mexico: Agua Verde Bay, Mulege). Meek, S. E., & Hildebrand, S. F., *Marine Fish of Panama*, 1, 1923: 74 (comparison with *Narcine brasiliensis*). Breder, C. M., Jr., *Bull. Bingham Oceanogr. Coll.*, 2 (1), 1928: 5, fig. 2 (Mexico: San Francisquito, Gonzago Bay, San Filipe Bay; Ballenas Bay on Carmen Island; color of young and adult, figure).

Narcine ommata Clark.

Range: Pacific Coast of Central America; exact locality unknown.

Field Characters: Tail thick with two dorsals and a caudal fin well developed; pelvics not notched on outer edge; skin smooth everywhere; electric organs present; pelvic fins separate; a brilliant ocellus in center of disk. Color markings strikingly similar to those of *Discopyge ommata* Jordan & Gilbert; but the species differs in not having the ventral fins united into a continuous disk as in *Discopyge*.

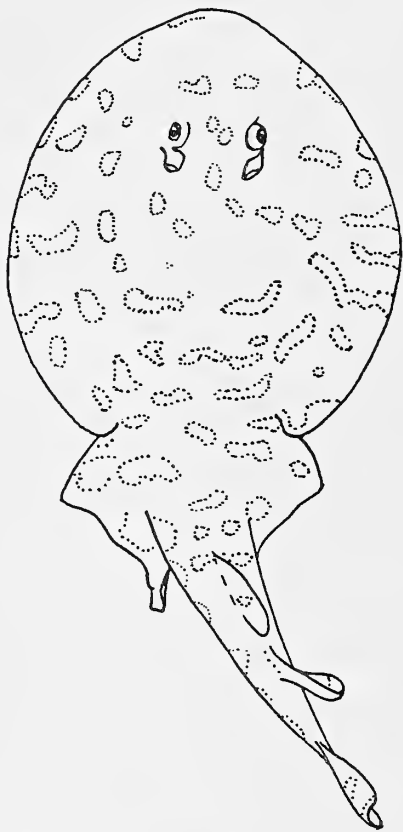
Study Material: None.

References: *Narcine ommata*, Clark, H. W., *Proc. Cal. Acad. Sci.*, 21, 1936: 383 (original description; type locality, Pacific coast of Central America, exact location unknown; type No. 5444, Mus. Cal. Acad. Sci., Ichthy.).

Narcine vermiculatus Breder.

Vermiculated Electric Ray.

(Plate I, Fig. 1).



Text-figure 3.

Range: Mexico, El Salvador. (Mexico: "west coast of Mexico," 15 miles west of San Benito, South Mexico, at 14° 40' 20" N. and 92° 40' 30" W.; El Salvador, off La Libertad, 13 fathoms.)

Field Characters: Tail thick, with two dorsals, caudal fin well developed; pelvics not notched on the outer edge; skin smooth everywhere; electric organs present; pelvic fins separate from each other; color as below. (Illustrations after Breder, 1928; 204 mm.).

Color: Deep chocolate brown above with numerous spots and vermiculations of white; ventral surface white except posterior edges of ventrals and pectorals which are slightly dusky; posterior edge of both dorsals and caudal edged with white; a single white spot a little longer than spiracle at the center of each dorsal; two irregular white bands across caudal; line bounding upper and lower coloration on peduncle, above dermal fold, wavy. In general the light marks tend to run transversely over body.

Size: Kumada records a two-foot specimen.

Study Material: 1 specimen, El Salvador: off La Libertad. Young male, (27,523), 58 mm., Dec. 16, 1937, dredged at station 198: D-1, 13 fathoms.

References: *Narcine vermiculatus*, Breder, C. M., Jr., *Bull. Bingham Oceanogr. Coll.*, 2 (1) 1928: 6, figs. 3 and 4 (original description; type locality, 14° 40' 20" N. and 92° 40' 30" W., 15 miles west of San Benito, South Mexico; type No. 1143, Bingham Oceanogr. Coll., Peabody Museum, Yale Univ.).

Narcine sp., Kumada T., & Hiyama, Y., *Marine Fish Pac. Coast Mexico*, 1937: 21, Plate 54, fig. B (short description, color, figure).

Discussion: Four specimens of this beautiful ray are now known, three of which are males. The nearest related species is *Narcine brasiliensis*, but differing from this, to mention only one of several characters, the Pacific ray has the pre-orbital snout in the disk length, 3 to 3.6 times, while in the Atlantic fish the proportion is 4.4 times. The variation in color and pattern in *brasiliensis* is extreme, and is apparently concerned with and influenced by locality, individuality and development.

This prepares us for acceptance of the corresponding but less extreme variation in the four known specimens of *vermiculatus*, as intraspecific.

In our 58 mm. ray the pattern is in the form of large, well-defined white spots on the body and central disk and pelvics, which become short, irregular bands on the disk margin, numbering 11 or 12 altogether. On the upper tail the white is in the form of 3 complete bands, and a 4th across the caudal fin. The 2nd and 3rd tail bands are enforced by a large spot on each dorsal. Both the dark color and several of the white bands overlap on the under side of the posterior half of both pectorals and pelvics.

The next ray in size is Breder's, which is three and a half times larger (204 mm.). Here the pattern deserves the specific name of *vermiculatus*, the white being reduced, and divided into small irregular spots and lines. In Kumada & Hiyama's plate of a ray of the same size (210

mm.), the pattern is again quite distinct. The white is still more reduced, and is faint, and in the form of a few meandering, irregular lines, most of which are on the outer margin of the disk and radiate outward. The tail bands are almost absent, but each unpaired fin still has a whitish line across it.

The 4th individual we know only from Kumada's brief mention of "other large specimen (2 feet)."

In both Breder's and our specimens the rims of the spiracles are smooth, and while Kumada & Hiyama mention "small tubercles" in their description, yet their plate, which is drawn in great detail, shows them smooth.

Discopyge Tschudi, 1846.

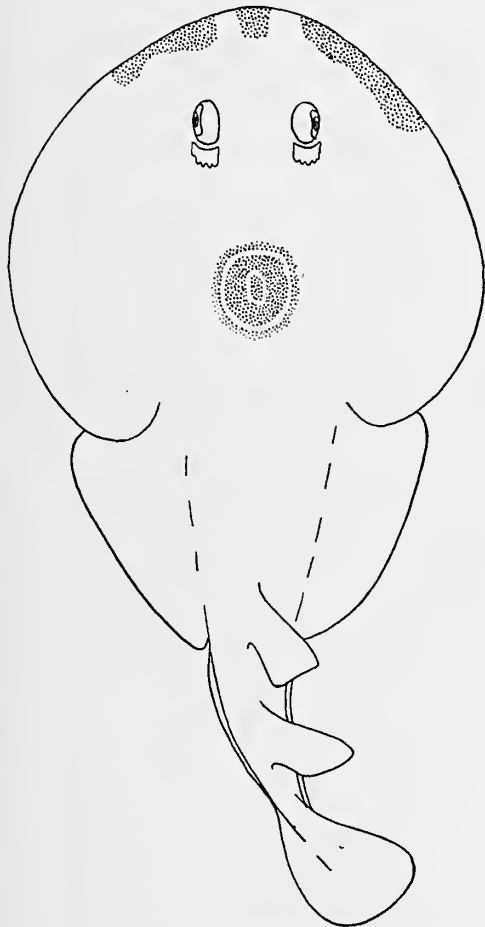
Key to tropical eastern Pacific species.

- 1a. A strongly marked, brilliant ocellus in the center of the disk *ommata*.
1b. No ocellus in center of the disk *tschudii*.

Discopyge ommata Jordan & Gilbert.

Ocellated Electric Ray.

(Plate I, Fig. 2).



Text-figure 4.

Range: Gulf of California to Panama (Mexico: Gonzaga Bay, Puerto Refugio, Inez Bay, Santa Cruz Island, San Francisco Island, Arena Point; Costa Rica: Port Culebra; Panama: 10 miles south of Pearl Islands, Bay of Panama).

Field Characters: Tail thick with two dorsals and a caudal fin; pelvics not notched on the outer edges; skin smooth everywhere. Provided with electric organs which generate sufficient power for adequate protection. Pelvic fins adnate to body. Color as below. (Illustration from specimen 25,236, 142 mm.)

Color: The color variations of six specimens are so extreme that no single description can cover all. This is not dependent on age, sex or locality and change of individual pattern can play but a slight part.

The commonest pattern is a light brown dorsal background, covered thickly with small, well-defined black dots. In the center of the back there is always a strongly-marked ocellus. This usually has a black or yellow ochre or rufous core, surrounded by a succession of solid or broken rings of alternating black and pale brown.

Other ocelli up to fourteen are scattered about on the upper surface, some like the spots of a jaguar, or again they may be almost solid. The most common situations are at the posterior inner angle of the pectorals, a pair close together between the central ocellus and the first dorsal fin, and one at the base of each dorsal fin. The preorbital area is free from dots and is marked with black and yellow ochre in the form of W's, M's and Y's. Below immaculate.

Our Arena specimens are wholly free from dots, the skin being faintly marbled, while the central ocellus has a small, bright rufous center, then a wide ring of black, outside of which is a narrow pale one. This concentration of pigment is evident in the post-pectoral and dorsal fin ocelli. There, extreme patterns are exhibited in specimens no more than 105 and 142 mm. apart in length.

A 65 mm. ray is thus described by Seale: "Mottled and marbled with brown over the back, with a distinct, round white spot surrounded by rings of black and white on the center of the back." Breder has found the same extremes of variation in specimens from the Gulf of California.

Size: The largest recorded specimen is our ray from Inez which measures 185 mm. in total length.

Local Distribution: These little rays have been taken not far from shore in 1 to 35 fathoms.

Abundance: Common at night in shallow water in Inez Bay. Elsewhere it has been recorded singly or in pairs.

Food: We found amphopods, small shrimps and worms in the stomachs. Also considerable quantities of very fine bits of quartz.

Breeding: In our largest specimen, a female of 185 mm. length, taken on April 10, the organs were considerably enlarged.

General Habits: At night, near shore, in the light of our flashes, these rays were clearly visible as they swam through mid-water or close to the bottom. Unharmred specimens, when picked up from the dredge hauls, gave forth an electric shock, especially if the fish was seized on each side of the ocellus, in the middle line of the body. The shock was sufficiently strong, if unanticipated, to make one drop the fish. It is said to generate as much as twenty volts. Three shocks in succession were noticed, the third weaker than the others.

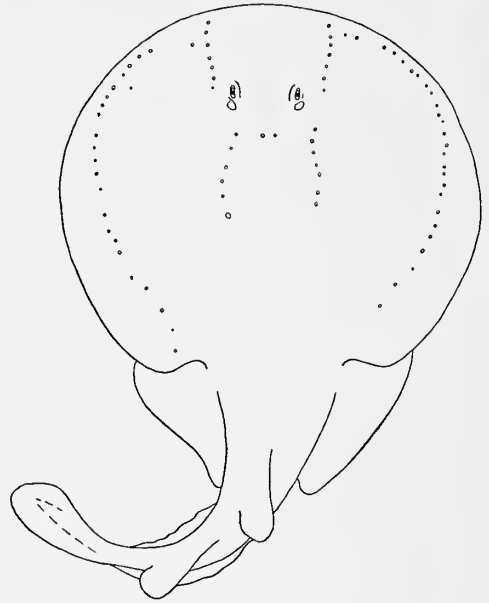
The conspicuousness of the pattern suggests the possibility of its serving a function of warning to vertebrate enemies.

Study Material: 11 specimens: Mexico: Inez Bay, 3 males, 2 females (25,774) 116 to 174 mm. April 13, 1936, speared at night in shallow water (one saved); Inez Bay, 1 male, 1 female (24,932) Col. Plate 31,168 and 185 mm. April 10, 1936, dredged, Station 141:D-1, in 7 to 9 fathoms; Inez Island, 1 male, (25,236) 142 mm. April 9, 1936, dredged in shallow water; Arena Bank, 1 male, 2 females (25,338) 105, 120, 155 mm. April 19, 1936, male dredged at Station 136:D-5 in 33 fathoms, females Station 136:D-6 in 35 fathoms.

References: *Discopyge ommata*, Jordan, D. S., & Gilbert, C. H., in Jordan, D. S. & Bollman, C. H., *Proc. U. S. Nat. Mus.*, 12, 1890: 151 (original description, color; type locality, 10 miles south of Pearl Islands, Bay of Panama). Jordan, D. S., & Evermann, B. W., *Fishes of North and Middle America*, 1896: 78 (short description). Osburn, R. C., & Nichols, J. T., *Bull. Amer. Mus. Nat. Hist.*, 35, 1916: 144 (Santa Cruz Island, Gulf of California). Meeke, S. E., & Hildebrand, S. F., *Marine Fishes of Panama*, 1923: 74 (short description). Breder, C. M., Jr., *Bull. Bingham Oceano. Coll.*, 2 (1), 1928: 8 (color variation, Gulf of California; Angel Island, Gonzago Bay, San Francisco Island). Beebe, W., *Bull. N. Y. Zool. Soc.*, 39, 1936: 236 (figure). Beebe, W., "Zaca Venture," 1938: 123, 300, fig. 10 (note on electric shocks, figure). Seale, A., *Allen Hancock, Pac. Exped.*, 9, 1940: 2 (color; Costa Rica: Port Culebra).

Size: The Peruvian specimen was 143 mm. in length. A male from the Atlantic measures 410 mm.

Study Material: None.



Text-figure 5.

References: *Discopyge tshudii*, Heckel, J. T., in Tschudi, J. J., *Fauna Peruana, Pisces*, 1845: 32, Pl. 6 (original description, type-locality between Huacho and Chancay); Steindachner, F., *Zool. Jahrb., Suppl.*, IV, 1898: 332, Plate 21, fig. 15 (description, figure). Abbott, J. F., *Proc. Acad. Nat. Sci. Phila.*, 1899: 329 (copy of original description). Garman, S., *Plagiostomia*, 1913: 303 (shortened translation of original description). Norman, J. R., *Discovery Reports, Coast Fishes*, 2, 1937: 11, fig. 3 (Record of several from Atlantic, Gulf of St. George, Argentina, figure).

***Discopyge tshudii* Heckel.**

Range: Reaches the middle of Peru at the edge of our province. Said to extend around Patagonia as far north in the Atlantic as the Rio Plata. (Peru: Between Huacho and Chancay.)

Description: Disk circular; tail less than half the total length. Mouth, eyes and spiracle in the anterior seventh of the total. Mouth small, protractile; teeth bands narrow; teeth minute, flat, inner margins acute angled. Eyes small. Spiracles much larger than the eyes, and a short distance behind; margins without papillae or projections. Gill apertures small, hindmost two behind the middle of the disk. Dorsals small, rounded, subequal; origin of first dorsal slightly in front of the hind margin of the pelvis; second dorsal reaching little behind the origin of the caudal. Pelvis broad, rounded, united behind the vent. Tail small, depressed, dermal folds prominent, posterior margin of caudal convex, supra-caudal portion of fin longer. (Illustration after Günther, 1898, 143 mm.)

Color: Dusky reddish-brown above, darker over the middle; dull whitish below.

FAMILY RHINOBATIDAE.

Key to tropical eastern Pacific genera.

- 1a. Width of disk 1½ to 1¼ times into the length of the disk; nostrils oblique; snout pointed, its angle 60°.....*Rhinobatus*.
- 1b. Width of disk equal to its length; nostrils transverse; snout shorter, obtusely pointed, its angle 85°.....*Zapteryx*.

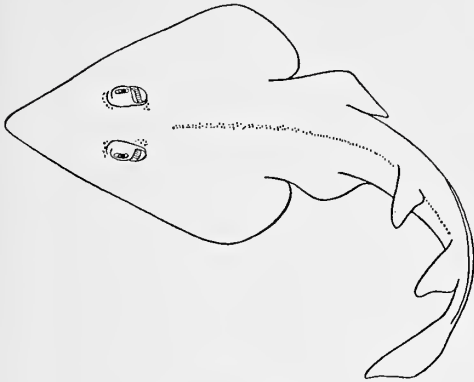
***Rhinobatus* Linck, 1790.**

Key to tropical eastern Pacific species.

- 1a. A single rudimentary spiracular fold.. *planiceps*.
- 1b. Two spiracular folds.
 - 2a. Rostral ridges close together for their anterior halves..... *productus*.
 - 2b. Rostral ridges separated for their whole length.
 - 3a. Rostral ridges rather broad; back with regularly arranged slate-colored blotches *glaucostigma*.
 - 3b. Rostral ridges narrow; back without blotches..... *leucorhynchus*.

Rhinobatus planiceps Garman.

Flat-headed Guitarfish.



Text-figure 6.

Range: Galápagos Islands and Peru. (Peru: Payta, Callao, Pacosmayo, Lobos de Tierra La Punta; Galápagos Islands.)

Field Characters: Flattened shark-like rays; snout narrow and elongate; tail thick and with two dorsals and a well-developed caudal fin; pelvics unnotched on outer edge; skin rough with scattered spines; nostrils oblique; a single, rudimentary spiracular fold. (Illustration after Garman, 1913, 448 mm.)

Color: Light olive green above, with numerous symmetrically placed dark blotches, with rather vague outlines. The dorsals, caudal, and outer parts of paired fins with slight rufous tinge; white below.

Size: The largest recorded specimen is 763 mm. in total length.

Abundance: Apparently common along the Peruvian coast.

Study Material: None.

References: *Rhinobatus planiceps*, Garman, S., *Bull. Mus. Comp. Zool.*, 6, 1879-1880: 168 (original description, 21 specimens from Payta, Callao, and Galápagos Islands). Garman, S., *Proc. U. S. Not. Mus.*, 3, 1880 (1881): 520 (description); Garman, S., *Bull. Mus. Comp. Zool.*, 17, 1888-1889: 89, Plate 24 (description of lateral-line canal system). Jordan, D. S., & Evermann, B. W., *Fish North and Middle America*, 1, 1896: 64 (description). Garman, S., *The Plagiostomia*, 1913: 283, Plate 17a (description, figure; Lobos de Tierra, Peru). Nichols, J. T., & Murphy, R. C., *Bull. Amer. Mus. Not. Hist.*, 46, 1922: 504 (Pascasmayo, Peru). Anonymous, *Bol. Mus. Hist. Not. "Jovier Prodo,"* No. 9, 1939: 122, 125 (La Punta, Peru).

Rhinobatus productus Ayres.

Northern Guitarfish; Shovel-nosed Shark.

Range: San Francisco south to Agua Verde Bay, Gulf of California. (Mexico: Cedros Island, Port San Bartholome, Turtle Bay, Magdalena Bay, Agua Verde Bay.)

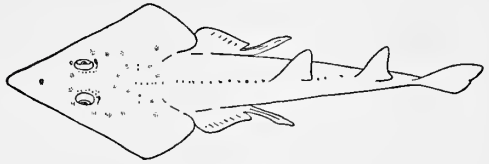
Field Characters: Flattened shark-like rays, snout narrow and elongate; a stout tail furnished with two dorsal fins and a caudal fin. Skin

covered with fine shagreen, with rows of hooked spines down the back and tail, and a small cluster at the shoulder; nostrils oblique; two spiracular folds; rostral ridges approximated along anterior half. Brownish-gray above, with a series of round, slaty spots. (Illustration after Kumada & Hiyama, 1937, 464 mm.)

Size: Reaches a length of over four feet.

Abundance: Reported as common in Turtle Bay.

Study Material: None.

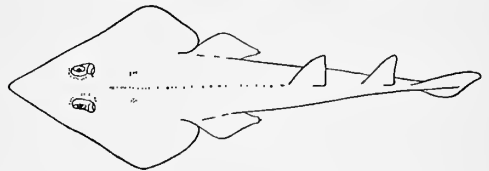


Text-figure 7.

References: *Rhinobatus productus*, Ayres, W. O., MS., Girard, C. F., *Proc. Acad. Not. Sci. Phila.*, 7, 1856: 196 (original description, Monterey, California). *Rhinobatus productus*, Osborn, R. C., & Nichols, J. T., *Bull. Amer. Mus. Not. Hist.*, 35, 1916: 142 (Mexico: Cerros I., Port San Bartholome and Agua Verde Bay). *Rhinobatus productus*, Wales, J. H., *Copeia*, 1932: 163 (Mexico: Turtle Bay, Magdalena Bay). Norman, J. R., *Proc. Zool. Soc. London*, 1926: 973, fig. 26 (description, figure, synonymy). *Rhinobatus productus*, Kumada, T., & Hiyama, Y., *Marine Fish Pacific Coast Mexico*, 1937: 18, Plate 50 (description, figure).

Rhinobatus glaucostigma Jordan & Gilbert.

Slaty-spotted Guitarfish.



Text-figure 8.

Range: Lower California to Ecuador (Mexico: San Bartolome Bay, Guaymas, Mazatlan; Ecuador: Bay of St. Helene).

Field Characters: Flattened, shark-like rays; snout narrow and elongate; tail thick with two dorsals and a well-developed caudal fin; pelvics not notched on outer edge; skin rough with scattered spines; nostrils oblique; two spiracular folds; rostral ridges widely separated and rather broad; back with regularly arranged, slate-colored spots. (Illustration after Kumada & Hiyama, 1937, 382 mm.)

Color: Brownish-gray above, with a series of round, slate-colored spots symmetrically arranged. Pectorals and pelvic fins with pale margins; a dark blotch and some irregular dark patches below the snout. (Norman, *Proc. Zool. Soc. London*, 1926: 970.)

Size: The largest published record is of a fish 762 mm. in length.

Local Distribution: Sandy bottoms in shallow water.

Abundance: There are exceedingly few records of this ray; at Mazatlan it is said to be very common on sandy bottoms.

Study Material: None.

References: *Rhinobatus glaucostigma*, Jordan, D. S., & Gilbert, C. H., *Proc. U. S. Nat. Mus.*, 6, 1884: 210 (original description, color, comparison with *R. productus* and *R. leucorhynchus*, Mazatlan); Evermann, B. W., & Jenkins, O. P., *Proc. U. S. Nat. Mus.*, 14, 1892: 132 (Guaymas, Mexico); Jordan, D. S., *Fishes of Sinaloa*, 1895: 387 (Mazatlan); Jordan, D. S. & Evermann, B. W., *Fishes of North and Middle America*, 1, 1896: 62 (description, color, Gulf of California); Boulenger, G. A., *Boll. Musei della R. Università di Torino*, 13, No. 329, 1898: 1 (Baie de St. Helene, Ecuador); Gilbert, C. H., & Starks, E. C., *Fishes of Panama Bay*, 1904: 14 (comparison with *leucorhynchus*); Garman, S., *Plagiostomia*, 1913: 282 (description, color, Gulf of California); Norman, J. R., *Proc. Zool. Soc. London*, 1926: 970, figure 23 (description, color, range, Mazatlan, figure); Breder, C. M., Jr., *Bull. Bingham Oceano. Coll.*, 2, (1) 1928: 5 (comparison with *leucorhynchus*).

Rhinobatus productus: Streets, T. H., *Bull. U. S. Nat. Mus.*, 7, 1877: 55 (San Bartolome Bay, Lower California).

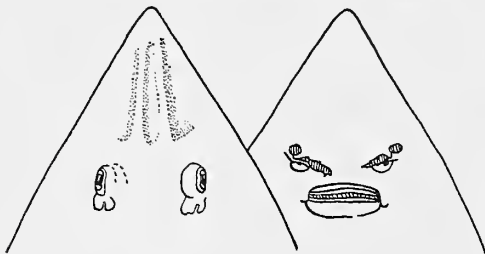
Rhinobatus leucorhynchus: Jordan, D. S., & Gilbert, C. H., *Bull. U. S. Fish Comm.*, 2, 1883: 105 (name only, Mazatlan).

Rhinobatus sp., Kumada, T., & Hiyama, Y., *Marine Fish West Coast Mexico*, 1937: 18, Plate 50, B (short description, figure, west coast Mexico).

Discussion: Kumada & Hiyama's *Rhinobatus* sp. has been placed in the synonymy of this species, although there are points of disagreement in the descriptions.

Rhinobatus leucorhynchus Günther.

White-snouted Guitarfish; Fiddlefish.



Text-figure 9.

Range: Mazatlan, Mexico, south to Guayaquil, Ecuador. (Mexico: Mazatlan, Tenacatita Bay, San Benito; Costa Rica: Gulf of Nicoya; Panama: Bahía Honda, Panama Bay; Colombia: Tumaco; Ecuador: Guayaquil).

Field Characters: Flattened shark-like rays; snout narrow and elongate; tail thick, with two dorsals and a well-developed caudal fin; pelvis unnotched on outer edge; skin rough with scattered spines; nostrils oblique; two spiracular folds; rostral ridges rather narrow; back without spots.

Color: Dark gray above, the snout and outer parts of disk paler, no spots or blotches. Lower parts pale, the distal part of snout dusky. Another fully adult specimen with ten, irregular, roundish spots scattered at random on the back. Younger individuals are said to be generally

lighter in color, with a few pale spots scattered over the upper parts.

Size: A female of 625 mm. has been recorded.

Local Distribution: Sandy bottoms in shallow water.

Breeding: Two young, about to be born, were taken from an adult ray, on April 9, in thirty fathoms, off San Benito in southern Mexico. Each measured 165 mm. in length. A ray 140 mm. long was taken in Tenacatita Bay, Mexico, on December 10.

Study Material: Not taken by us. A single ray of this species which had been caught in the Gulf of Nicoya, was identified in the collection of the museum at San Jose, Costa Rica.

Discussion: There seems considerable likelihood of identity between *leucorhynchus* and *glaucostigma*, as indicated by the following: Gilbert & Starks admit very close relationship between the two forms, but give three apparent differences: pattern, rostral ridges, shape of snout and size of posterior gill-slit.

Stark says that the Ecuadorian specimen of *leucorhynchus* in snout, rostral ridges and disk outline is intermediate between a Panama specimen and a Mazatlan specimen of *glaucostigma*. In *leucorhynchus* the dorsals are thought to be darker and the shagreen is rougher and coarser.

Breder notes the irregularity of the pattern in his individual of *leucorhynchus* and adds, "This suggests the possibility of *R. glaucostigma* Jordan and Gilbert being identical with it or a race."

This can be satisfactorily settled only by a study of a reasonably adequate series of individual rays.

References: *Rhinobates leucorhynchus*: Günther, A., *Proc. Zool. Soc. London*, 1866: 604 (original description, Panama).

Rhinobatus leucorhynchus: Günther, A., *Trans. Zool. Soc. London*, 6, 1869: 396, 490. (description of type, Pacific coast of Panama); Günther, A., *Cat. Fish. Brit. Mus.*, 8, 1870: 444 (description and illustration of head); Garman, S., *Proc. U. S. Nat. Mus.*, 3, 1881: 517 (description, Panama); Jordan, D. S., & Gilbert, C. H., *Bull. U. S. Fish Comm.*, 2, 1882: 105 (Mazatlan, Mexico); Jordan, D. S., *Proc. U. S. Nat. Mus.*, 8, 1886: 364 (Panama); Jordan, D. S., & Evermann, B. W., *Fishes North and Middle America*, 1896: 62 (description, color, Panama and vicinity); Gilbert, C. H., & Starks, E. C., *Fishes Panama Bay*, 1904: 14 (comparison with *glaucostigma*); Starks, E. C., *Proc. U. S. Nat. Mus.*, 30, 1906: 762, 763 (comparison with *glaucostigma*, Gulf of California, Panama, Ecuador); Garman, S., *The Plagiostomia*, 1913: 282 (description, color); Wilson, C., *Ann. Carnegie Mus.*, 10, 1916: 58 (Tumaco, Colombia); Meek, S. E., & Hildebrand, S. F., *Marine Fishes Panama*, 1923: 68 (description, color, Mazatlan to Ecuador); Norman, J. R., *Proc. Zool. Soc. London*, 1926: 971 (description, illus. of head, type length); Breder, C. M., Jr., *Bull. Bingham Oceano. Coll.* 2 (1), 1928: 4 (color, comparison with *glaucostigma*; San Benito, Mexico; Bahía Honda, Panama).

Rhinobatus leucorhynchus: Seale, A., *Allan Hancock Pacific Exped.*, 9, No. 1, 1940: 2 (Tenacatita Bay, Mexico).

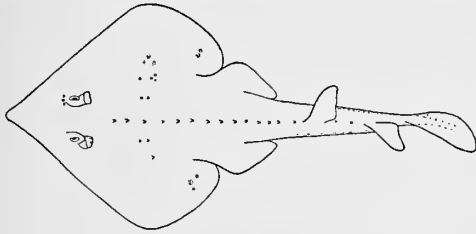
Zapteryx Jordan & Gilbert, 1880.

Zapteryx exasperata (Jordan & Gilbert).

Rough-skinned Guitarfish.

Range: San Diego and the Gulf of California south to Panama. (Mexico: Gonzago Bay, San Felipe Bay, Espiritu Santos Island; Panama: Panama Bay.)

Field Characters: Flattened, shark-like rays; tail thick with two dorsals and a well-developed caudal fin; no notch on outer edge of pelvics; skin rough with scattered spines; color not uniformly black; nostrils transverse; disk dark, with black-edged yellow spots, or strong transverse bands. (Illustration after Kumada & Hiyama, 1937, 485 mm.)



Text-figure 10.

Color: The two extremes of pattern and color are as follows; grayish-brown above, a band of dark brown near the ends of the nostril ridges; between this and another dark band which crosses the bases of the ridges, there is a light band; a band across the head between the eyes is somewhat confluent with the band in front of it, except for a dark spot on the posterior angle of each pectoral. In the second type of extreme pattern, the disk has several rough, yellowish spots as large as the pupil, each spot ocellated with black.

Size: Reaches a length of about three feet.

Local Distribution: Shallow waters near shore.

Study Material: None.

Discussion: The variation in pattern and color removes all possibility of these being specific characters, and in all other respects *xyster* appears to be indistinguishable from *exasperata*.

References: *Platyrhina exasperata*, Jordan, D. S., & Gilbert, C. H., *Proc. U. S. Nat. Mus.*, 3, 1881: 32 (original description; type locality, San Diego, California).

Syrhina exasperata, Jordan, D. S., & Gilbert, C. H., *Proc. U. S. Nat. Mus.*, 5, 1882 (1883): 621 (color, Panama); Breder, C. M. Jr., *Bull. Bingham Oceanogr. Coll.*, 2, 1928: 5 (Mexico: San Francisco Bay, Gonzago Bay, San Felipe).

Rhinobatos exasperatus, Jordan, D. S., *Proc. U. S. Nat. Mus.*, 8, 1886: 364 (Panama).

Zapteryx xyster, Jordan, D. S., & Evermann, B. W., *Fishes North and Middle America*, 1, 1896: 65 (original description, type locality, Panama); Norman, J. R., *Proc. Zool. Soc. London*, 1926: 980 (comparison with *exasperatus*). Brock, V., *Copeia*, 1938: 130 (Espiritu Santo Island, comparison with *exasperata*).

Xapteryx xyster, Kumada, T., & Hiyama, Y., *Marine Fish Pacific Coast Mexico*, 1937: 19, Plate 52.

Family PRISTIDAE.

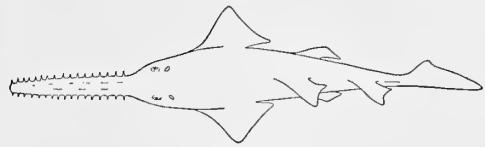
Pristis, Klein, 1779.

Key to tropical eastern Pacific species.

- 1a. Origin of first dorsal fin well in advance of the origin of the pectorals; lower lobe of caudal fin present, but small; 14 to 23 teeth along each edge of the rostrum. *zephyreus*.
1b. 24 to 32 teeth along each edge of the rostrum.
? *pectinatus*.

Pristis zephyreus Jordan & Starks 1895.

Sawfish.



Text-figure 11.

Range: Mexico to Ecuador. (Mexico: Mazatlan; Guatemala: Chiapas; Costa Rica: San Juan del Sur; Panama: Balboa, Rio Grande at Miraflores, Rio Chucanaque; Colombia: Rio San Juan; Ecuador: Guayaquil.)

Field Characters: Shark-like rays with an elongate, depressed body; snout produced into a flat, very long rostrum, armed along each lateral edge with a series of 17 to 23 large teeth; lower lobe of caudal small; origin of first dorsal in advance of the pelvics. (Illustration from figure of closely related *P. perotteti*, after Day, 1888.)

Study Material: No living individuals were observed or captured. A large rostrum (No. 28,723) of this species was obtained in San Juan del Sur, Costa Rica, Jan. 10, 1938, from a fisherman, who had taken the sawfish himself. The snout measures 900 mm. from the tip to the origin of the proximal, lateral pair of teeth; at the latter place the width of the snout is 175 mm. and the length of the longest tooth is 45 mm.

References: *Pristis zephyreus*, Jordan, D. S., & Starks, E. C., in Jordan, D. S., *Fishes of Sinaloa*, 1895: 383 (original description; comparisons of various descriptions of various authors; type locality, Mazatlan, Mexico; type in Stanford University). Gilbert, C. H., & Starks, E. C., *Fishes of Panama Bay*, 1904: 14 (amended description, specimens from Rio Grande at Miraflores, Panama).

Pristis microdon, Meek, S. E., & Hildebrand, S. F., *Marine Fishes of Panama*, 1, 1923: 66 (tidal streams near Balboa, Panama, 22 specimens, 800-1075 mm., description). Breder, C. M., Jr., *Bull. Amer. Mus. Nat. Hist.*, 57, 1927: 99 (Rio Chucanaque, Panama, 5 specimens, 770-965 mm., notes on ecology). Breder, C. M., Jr., *Bull. Bingham Oceanogr. Coll.*, 2 (1), 1928: 4 (refers to last mentioned reference, note on habits; under *P. pectinatus*).

Pristis perotteti, Günther, A., *Cat. Fishes Brit. Mus.*, 8, 1870: 437 (Chiapas, Guatemala). Steindachner, F., *Denkschr. Akad. Wiss. Wien.*, 42, 1880: 102 (fresh and brackish water around Guayaquil, Ecuador; two specimens, 790 and 870 mm.). Jordan, D. S., & Gilbert, C. H., *Bull. U. S. Fish Comm.*, 2, 1882 (1883): 105 (Mazatlan, Mexico). Wilson C., *Annals Carn. Mus. Pittsburgh*, 10, 1916: 58 (Guayaquil, Ecuador). Eigenmann, C. H., *Indiana Univ. Studies*, 46, 1920: 10 (Rio San Juan, Colombia). Eigenmann, C. H., *Memoirs Carn. Mus., Pittsburgh*, 9, 1922: 25 (Rio San Juan, Colombia).

Pristis antiqouorum, Günther, A., *Trans. Zool. Soc. London*, 6 (7), 1868: 397 (Chiapas, Guatemala).

Discussion: This species has been merged with *P. microdon*, and is so considered in many publications. Until good comparisons are made with materials from other oceans we prefer to maintain the Pacific coastal form as a separate species.

? *Pristis pectinatus* Latham.

Sawfish.

Range: Acapulco, Mexico is the only definite locality record within our area on the Pacific coast.

Field Characters: Shark-like rays with an elongate, depressed body; snout produced into a flat, very long rostrum, armed on each side with 24 to 32 teeth.

Study Material: No live fish observed or collected; two small rostrums were purchased at Acapulco, Mexico, Nov. 26, 1937. They measure 172 and 175 mm. from the tips to the proximal pair of teeth; width at this base 28 mm.; number of teeth 27 right, 27 left, and 26 right, 28 left respectively (Nos. 28,724, 28,725).

References: ? *Pristis pectinatus*, Latham, J., *Trans. Linn. Soc. London*, 2, 1794: 278 ("in the ocean."). Breder, C. M., Jr., *Bull. Bingham Oceanogr. Coll.*, 2 (1), 1928: 4 (no definite locality, west coast of Central America or Mexico; 2 specimens, 710 and 724 mm. and rostrum of a third specimen).

Discussion: Further study may show these Pacific sawfish to be another species.

Family RAJIDAE.

Key to tropical eastern Pacific genera.

- 1a. Rostral cartilage produced forward from the skull, stiffening the rostrum. *Raja*.
- 1b. Rostrum soft, flexible, lacking the rostral prolongation of the cranium. *Psammodontus*.

Raja Linnaeus, 1758.²

Key to tropical eastern Pacific species.

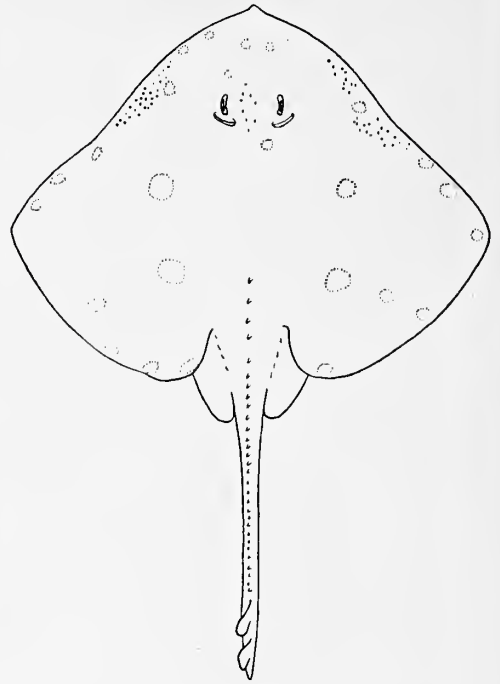
- 1a. No spines present about the eye; 33 rows of teeth. *aguja*.
- 1b. Spines present about the eye; 37 to 44 rows of teeth.
 - 2a. Three large spines about the eye, one in front and two behind (see illustration) *badia*.
 - 2b. Usually more than three spines about the eye, the spines smaller in size.
 - 3a. Three or four rows of spines between the eye and the edge of the disk; a spine on each shoulder; an obscure darkish patch near the base of the pectoral fin on the dorsal surfaces. *equatorialis*.
 - 3b. No rows of spines below the eyes; no tubercles or spines on the shoulders.
 - 4a. A series of spines or prickles along the middle of the back, a few of the anterior ones being quite large; a dark ring on the upper surface near the base of the pectoral fin (Cedros Island, northward). *inornata*.
 - 4b. A single median spine on the back; no dark ring near the base of the pectoral fin on the upper surface (Ecuador) *ecuadoriensis*.

² This key should be used with great caution, as our knowledge of the tropical eastern Pacific forms of this genus is fragmentary.

Two species of the genus *Raja* have been reported by Kumada & Hiyama from the "west coast of Mexico." Whether these fish belong to the tropical eastern Pacific fauna or to that of the colder waters further north we do not know. Because of scanty material and lack of familiarity with the group, we do not attempt to give these specimens a name or to place them in the synonymy of some other form. We have included copies of Kumada & Hiyama's descriptions under the heading of "*Raja* sp. A." and "*Raja* sp. B."

Raja aguja Kendall & Radcliffe.

Peruvian Ray.



Text-figure 12.

Range: Near Aguja Point, Peru (Lat. 5° 47' S., Long. 81° 24' W.), in 536 fathoms.

Field Characters: Caudal fin absent or only a slight fold of skin; two dorsal fins crowded together near tail tip; pelvics notched on outer edge; skin rough; thirty-three rows of teeth. Color, purplish-brown, with or without scattered pale, good-sized spots. (Illustration after Kendall & Radcliffe, 1912, 480 mm.)

Size: Grows to 480 mm.

Study Material: None.

References: *Raja aguja*, Kendall, W. C., & Radcliffe, L., *Mem. Mus. Comp. Zool.*, 35, 1912: 78, 167, Plate 1, figs. 1 and 2 (original description, color; type locality: near Aguja Point, Peru).

Raja aguja, Garman, S., *The Plagiostomia*, 1913: 358 (re-description of one of the types).

Discussion: The female specimen in the original description appears as if it might be assigned to *Psammodontus*.

Raja badia Garman.

Range: Gulf of Panama. (Thirty miles east of Capa Mala, Lat. 7° 5' 30" North, Long. 79° 40' West), in 1270 fathoms.

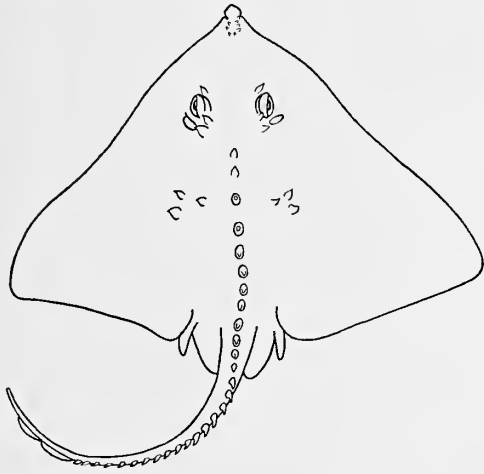
Field Characters: Ray with caudal fin absent, a low dermal keel on upper and lower sides of tip of tail; two dorsal fins crowded together near tip

of tail; pelvic fin notched on outer edge; skin rough, with a single median row of large tubercles down back and tail, conspicuous, large spines about the eye. (Illustration after Garman, 1899, 257 mm.)

Color: Chocolate brown above and below; narrow white areas about the mouth, and a white spot immediately behind the middle of the shoulder girdle.

Size: Length of only known specimen, 257 mm.

Study Material: None.



Text-figure 13.

Breeding: Two egg-cases which, as Garman writes, are "probably *R. badia*," were taken in two hauls by the *Albatross*, on Feb. 24, at almost the same locality, about fifty miles south-west of Mariata Point, Panama, in 465 and 782 fathoms respectively. Garman figures one of them and describes them as follows: "The egg case itself, without the tendrils, is 64 by 90 mm. The horns are mutilated, evidently they were of considerable length; their bases are stout and thick. Over the entire surface the case is covered with fine villi or pile, in longitudinal series, which though harsh to the touch, gives the appearance of a soft rich, black velvet. The second specimen has a longer, closer pile."

References: *Raja badia*, Garman, S., *Mem. Mus. Comp. Zool.* 24, 1899: 22, Plate 6, figs. 1-3 (original description, color, egg cases; type locality, Panama Bay).

Raja badia, Garman, S., *The Plagiostomia*, 1913: 357 (description, color).

Raja ecuadoriensis nom. nov.³

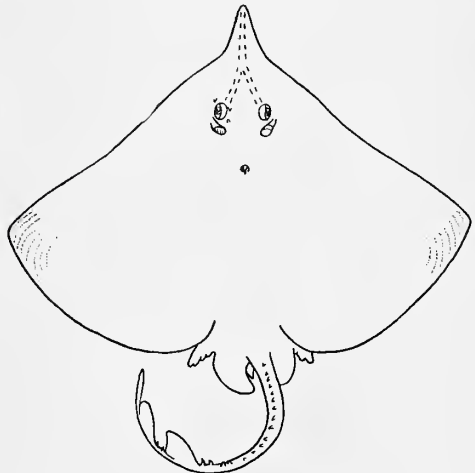
Range: San Helena Bay, Ecuador.

Description: The figure adjacent and the following translation are from Tortonese's description and account.

³ Nom. nov. for *Raja steindachneri* Tortonese, 1939, not of Delfin, 1901.

"*Raja steindachneri*. Delf. (Tav. 1).

"Length 388 mm., disk length 224 mm. at the widest place, which is one-third wider than long. The line which connects the tip of the snout with the center of that which goes from one tip of the pectorals to the other is somewhat less than half of this latter. The line from the tip of the snout to that of one pectoral intersects the margin of the body slightly near the tip of the pectorals, and comprises one and a half times the length of the disk. The pectorals have convex angles, almost acute. The posterior ones are rounded. The anterior margin is slightly sinuous, forming on each side two slightly marked re-entrances which render it prominent in relation to the eyes. The pectorals reach to the middle of the ventrals, which are clearly bilobar and measure three-quarters of the length of the snout. The latter is long and acute, much straitened toward the tip which is rounded; the longitudinal diameter of the eye is comprised five and a half times in its length, the interorbital space three times. Rostrate angle of about 45°. The snout is a little less than a third of the length of the disk. The rostrate cartilage is narrow and robust, united in its distal three-fifths, forked at its base. The interorbital space is markedly concave. The orbits have small *spiracula*. The mouth is a little curved; its width is comprised one and three-fifths times in the pre-nasal part of the snout. 37/37 teeth, with a central triangular point. The nasal valves are fringed on the margin turned toward the mouth. Small *pterygopodia*; the free part measures 8 mm. The tail is depressed, with a longitudinal cutaneous fold on each side extending to the caudal one. The length of the approximately equal dorsal fins is a third of the snout; they are separated by a space rather smaller than half the base of the first dorsal fin; the second is united with the caudal one, which is placed low, and double the length of the eye.



Text-figure 14.

"Nearly all of the body is smooth. Two spines, with some other minute ones, stand before the orbit, two placed right above it, and some very small ones above the *spiracula*. A little behind these, and in the middle of the back stands a single strong isolated spine. Near the outer angle of the pectorals run 8 unequal series of small spines, arched more or less parallel to one another, and parallel also to the margin of the body, extending farther backward than forward. The dorsal median line of the tail is occupied by a series of 17 robust spines inserted into elliptical and laterally compressed *scutelli* that are not very much unequal in their dimensions; two other spines are placed between the dorsals. A fine band of tiny spinules follows the ventral margin, characteristics which distinguish the male: its total length is 393 mm., of which 178 make up the tail, but the *pterigopodia* measure 118 mm. This fact, combined with other small morphological differences might lead to the supposition that the Ecuador race represents a heretofore unknown species. It is however, impossible for me to ascertain this now, and since I am acquainted with *R. steindachneri* only through the treatise cited, I feel justified in the assumption that the specimen studied belongs to this species, observed until now near the coasts of Chile (type of Iquique) and Peru, but spreading also farther North.

"The races, limited perhaps to a small number of forms, which live in the western regions of South America, are not yet well known; concerning them comparative studies of a certain breadth are still lacking."

Reference: *Raja steindachneri* (not of Delfin) Tortonese, E., *Boll. Musei Zool. Anat. comp. Torino*, 1939 (3) 47, no. 89: 3-5, Plate 1 (description, figure, Ecuador).

Discussion: Tortonese's description and figure are based, according to his text, upon Evermann & Kendall's description of a ray⁴ that the latter assigned to *Raja steindachneri* Delfin, which in turn was based upon Steindachner's *Raja chilensis*, 1896. A comparison of Tortonese's figure with the original plate and description of *Raja chilensis* shows that the latter is quite properly placed in the synonymy of *Psammobatus lima* Poepfig, that Tortonese's fish with its prominent rostral cartilage was correctly assigned to the genus *Raja* and that it bears no resemblance to Steindachner's *chilensis*. It is therefore necessary to give another name to Tortonese's ray.

Raja equatorialis Jordan & Bollman.

Range: Gulf of Panama in 33 fathoms, 7 miles south of Pearl Islands. (8° 6' 30" N., 78° 51' W.)

Field Characters: Rays without distinct caudal fin; two dorsal fins near tip of tail; pelvic fin notched at outer end; large spines present around eye; three prominent rows of spines or tubercles on the tail.

Color: Light brown, spotted with paler, back

with obscure reticulations of the ground color, forming honey-comb-like markings surrounding paler markings; an obscure, roundish dusky blotch at middle of base of pectorals, and a darker one near their posterior base; edges of ventral and pectoral fins and the snout pale; dark markings on interorbital area and below eye. No markings below.

Size: The only known specimen is 14 inches long.

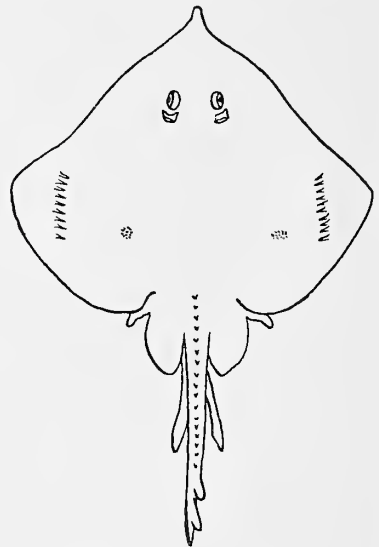
Study Material: None.

References: *Raja equatorialis*, Jordan, D. S., & Bollman, C. H., *Proc. U. S. Nat. Mus.*, 12, 1890: 150 (original description, color; type locality, Gulf of Panama; type No. 41,132, U. S. Nat. Mus.). Meek, S. E., & Hildebrand, S. F., *Marine Fishes of Panama*, 1, 1923: 71 (description, color). Gilbert, C. H., *Proc. U. S. Nat. Mus.*, 48, 1915: 308 (re-examination and description of the type).

Discussion: This ray is related to *Raja inornata*, from which it is apparently distinguished by having four rows of spines below the eyes, a series of stout spines on each side of the tail in the male, and no prickles on the back except the median series and the spine on each shoulder. Considering the variability found in *R. inornata*, a comparison between the type of *equatorialis* and specimens of *inornata* would be advisable. However, Gilbert (l. c.) states in his reexamination of the type of *equatorialis* that "*R. equatorialis* is not very closely related to any other American species."

Raja inornata Jordan & Gilbert.

California Skate.



Text-figure 15.

Range: Straits of San Juan de Fuca south to Cedros Island, Lower California.

Field Characters: Disk broad, diamond-shaped, anterior margins undulating. Caudal absent, two dorsals near tail tip; pelvics notched; small

⁴ Evermann, B. W., & Kendall, L., *Bull. U. S. Nat. Mus.*, 95, 1917: 14.

prickles along the mid back, larger ones on snout and between eyes, and 3 to 5 rows on back of tail. (Illustration after Barnhart, 1936.)

Color: Dark olive brown above, with a small dark ring at the base of each pectoral, and sometimes two other pale spots on the pectorals. Our half-grown specimen has the back covered with many, faint, dark spots and a lesser number of light ones; a narrow, pale blue edge around pelvic fins. Lower parts pale, mottled with dusky on central portions of fish.

Size: Reaches a length of two and a half feet.

Local Distribution: On the bottom of shallow water along the coast, as deep as seventy-six fathoms.

Abundance: From San Diego northward said to be very abundant.

Food: Specimen No. 25,688 had six small shrimps in its stomach; *Solenocera mutator* Burkenroad, 1 male; *Crago zaca* Chace, 4 females (1 ovigerous); *Crago resima* (Rathbun), 1 ovigerous female. All had been swallowed whole.

Study Material: 1 specimen. Dredged from Station 126:D-8, (East of Cedros Island, Lower California) in 48 fathoms on muddy bottom, female (25,688) length, 365 mm., May 22, 1936.

References: *Raja binoculata*, Jordan, D. S., & Gilbert, C. H., *Proc. U. S. Nat. Mus.*, 3, 1880: 134 (description, indefinite locality, San Francisco and Pacific Coast).

Raja inornata, Jordan, D. S., & Gilbert, C. H., *Proc. U. S. Nat. Mus.*, 4, 1881: 73 (reference to description given in preceding reference). Garman, S., *The Plagiostomia*, 1913: 347 (description of young specimen).

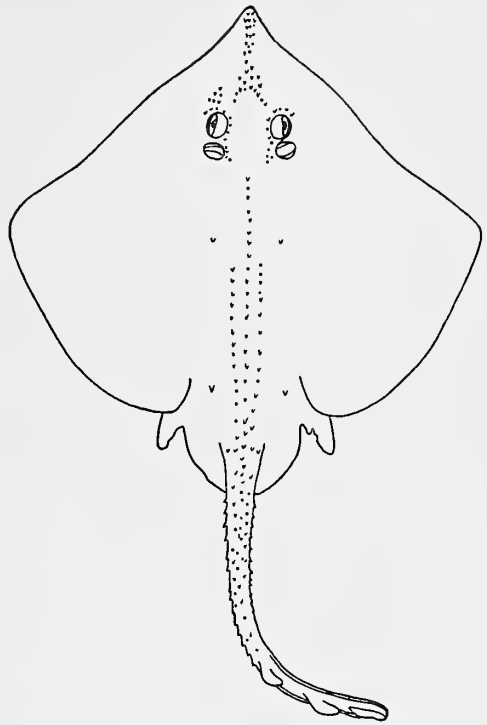
Raja inornata, Gilbert, C. H., *Rep. U. S. Fish Comm.*, 19, 1893 (1895): 462, 475 (description embryo, young and adults). Gilbert, C. H., *Proc. U. S. Nat. Mus.*, 48, 1915: 306 (description of embryo in egg case). Hubbs, C. H., *Copeia*, 86, 1920: 81 (development of dorsal spines).

Discussion: The half-grown female in our collection extends the range southward three hundred miles.

Raja sp. A.

Range: "Pacific Coast of Mexico." (Kumada & Hiyama).

Description: "Disk broader than long, anterior edge of pectoral convex; snout sharply pointed. Body, except ventrals covered with small sharp prickles. 10 to 15 small distinct spines along upper margin of orbit, from anterior end of orbit to posterior end of spiracle. Several spines in a group on shoulder; a pair of blunt processes in pelvic region. A row of sharp, rather hooked, spines along middle of back, from posterior of spiracle to caudal; beside this, 4 rows of smaller spines run parallel to median row, those becoming larger and hooked at tail, spines of inner rows few in number in tail, those of outer rows more numerous than median row. Back brownish gray, except sides of snout; a pair of large ocelli, consisting of black concentric ring, surrounded by a fainter area, at the middle of the pectoral fin. Lower surface white, posterior margin of pectorals and ventrals rather grayish, tail dark. Lower side of the snout and the anterior half of the anterior margin of the pectoral covered with



Text-figure 16.

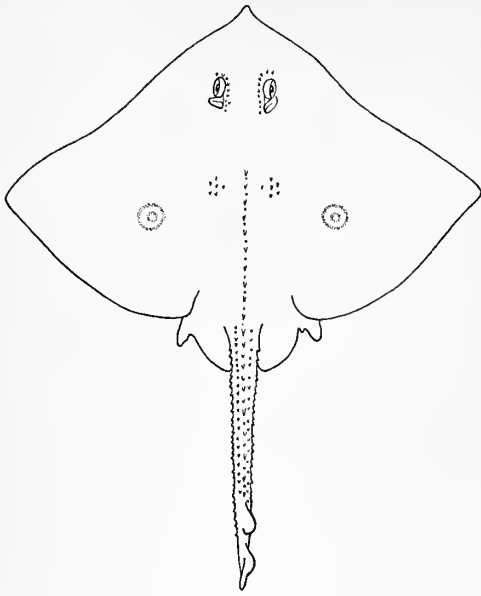
small prickles; other parts of lower surface smooth. The fish closely resembles *Raja stellulata* Jordan and Gilbert, but differs from it in having 5 rows of prickles on body and tail, and distinct concentric ocelli on middle of pectoral. Reaches 3 feet."

Reference: *Raja* sp., Kumada, T., & Hiyama, Y., *Marine Fishes West Coast of Mexico*, 1937: 19, Plate 53.

Raja sp. B.

Range: "Pacific Coast of Mexico." (Kumada & Hiyama).

Description: "Outline of the body closely resembles that of above species [*Raja* sp. A]. Body covered with less prickles; upper surface almost naked: anterior margin of the angle of the pectoral fin and the center of the body slightly roughened by small tubercles; lower surface of the body smooth, except anterior half of the margin of the pectorals. Spines of body rather smaller than forgoing species, not hooked; ten or more small spines on upper margin of the orbit, from anterior of eye to end of spiracle; a pair of groups of spines, each consisting of two or three flat tubercles, on shoulder; a pair of blunt spines on pelvic region; a row of large spines along middle of the body from behind spiracles to caudal, besides this a pair of rows of spines from middle of body to caudal parallel to median row, outer side of them, another



Text-figure 17.

pair of the rows of spines extends along middle line in tail; these all similar in size. Colour brownish gray above, speckled with small dark spots. Lower surface of body white, posterior margins of the pectoral and ventral grayish, lower side of the tail dark. Rather small in size. This also resembles *Raja stellulata*, but differs in the distribution of the spines on the upper side of the body and the tail, and in coloration."

Reference: *Raja* sp., Kumada, T., & Hiyama, Y., Marine Fishes West Coast of Mexico, 1937: 20, Plate 54, Fig. A.

***Psammobatis* Günther, 1870.**

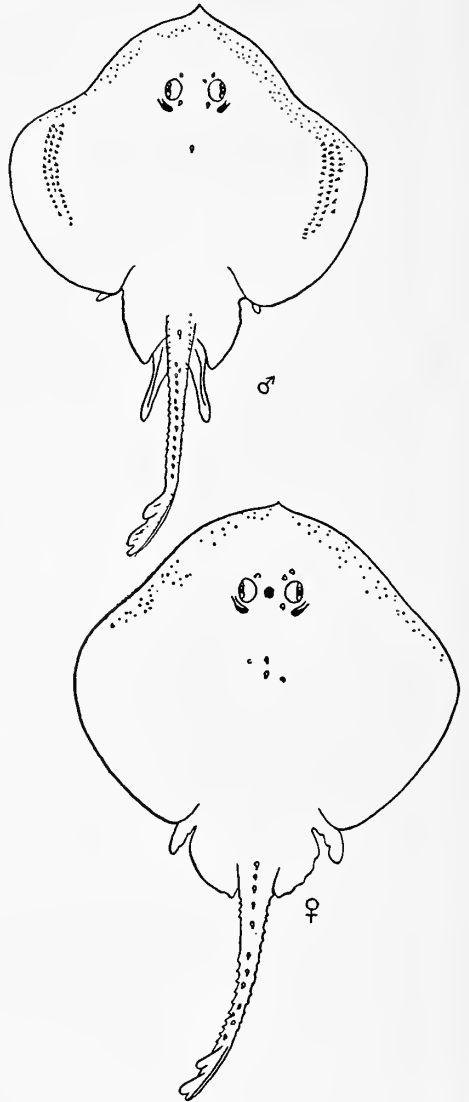
Key to tropical eastern Pacific species.⁵

- 1a. Interorbital width equal to or slightly more than the longitudinal diameter of the eye. *scobina*.
- 1b. Interorbital width 2 to 4 times the longitudinal diameter of the eye.
 - 2a. A median series of 6 or 8 spines on middle of the back. *brevicaudatus*.
 - 2b. No median series of spines on the middle of the back.
 - 3a. 10 to 11 large spines along the upper surface of the tail; upper surfaces of disk with minute spinules in a patch on the anterior margin of the pectoral fins, on snout, round the eyes and along middle of back; lower surfaces with a narrow patch of spinules along the anterior margin of the pectorals. *lima*.
 - 3b. 25 spines along the upper surface of the tail; disk above and below covered with spinules, these are more abundant in a

⁵This key has been adapted and modified from the recent revision of the genus by Norman (*Discovery Reports*, 16, 1937: 28-35, figs. 10, 11). Keys and complete synonymies can be obtained from this paper. See also *Raja aguja*.

• round cluster between the eyes and on the forehead and snout; lower surfaces lacking these spinules in a small area immediately around and behind the anus *spinosissimus*.

***Psammobatis scobina* (Philippi).**



Text-figure 18.

Range: Argentina, Patagonia, Chile, Ecuador. (Ecuador: San Elena Bay).

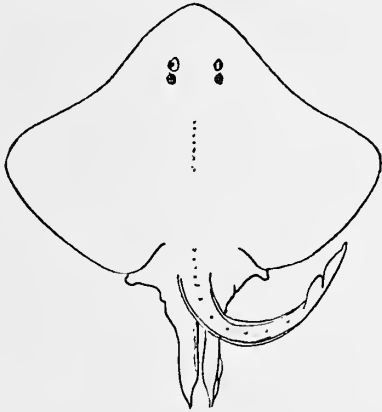
Field Characters: Somewhat diamond-shaped rays without caudal fin and with two dorsal fins crowded far back on the tail; snout soft, without an internal rostral prolongation of the cranium; interorbital space equal to or slightly greater than the diameter of the eye. Brownish or grayish, spotted or mottled with dark brown and

with some small indistinct ocelli scattered over the disk; lower surface uniformly white. (Illustration after Norman, 1937, 352 and 384 mm.)

Study Material: None.

References: See Norman, l. c., 29, 30. Add the following: *Malacorchina mira*, Tortonese, E., *Boll. Mus. Zool. Anat. Comp. Univers. Torino*, 47, ser. 3, No. 89, 1937: 5 (Ecuador: Bahia di S. Elena).

Psammobatis brevicaudatus Cope.



Text-figure 19.

Range: Ecuador and Peru. (Ecuador: San Elena Bay; Peru: Pacasmayo Bay.)

Field Characters: Small rays lacking a caudal fin and with two dorsal fins placed far back on the tail; snout soft, without an internal rostral prolongation of the cranium; interorbital space greater than length of eye plus the spiracle. Back plumbeous with darker shades; middle of anterior part of snout with a dark spot behind it. (Illustration after Fowler, 1910.)

Size: The two known specimens are 307 and 383 mm. long.

Study Material: None.

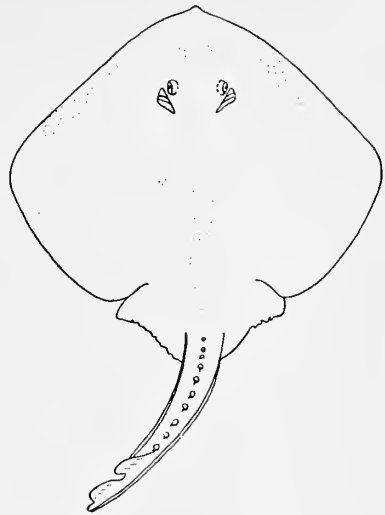
References: *Psammobatus brevicaudatus*, Cope, E. D., *Proc. Amer. Philo. Soc.*, 17, 1877: 48 (original description; type locality, Pacasmayo Bay, Peru). Fowler, H. W., *Proc. Acad. Nat. Sci. Phila.*, 1910: 471, fig. 2 (name only, figure of type). Garman, S., *The Plagiostomia*, 1913: 371 (description, color). Norman, J. R., *Discovery Reports*, 16, 1937: 35 (description).

Malacorchina brevicaudata, Tortonese, E., *Boll. Mus. Zool. Anat. Comp. Torino*, (3) 47, 1939: 6 (description, color; Ecuador: Baía de San Elena).

Psammobatis lima (Poepfig).

Range: Peru and Chile.

Field Characters: Diamond-shaped rays without caudal fin; two dorsal fins placed far back on a stout tail; snout soft, lacking the rostral prolongation of the cranium; length of snout $5\frac{1}{2}$ to $6\frac{1}{3}$ in width of the disk. Upper surface of disk mainly smooth, with areas of minute spinules on anterior margins of the pectoral fins, on the snout, round the eyes and along the back; large spines sometimes present on the upper surface of the tail, sometimes an irregular row of spines



Text-figure 20.

from nape joining the row on the tail. More or less uniformly grayish or brownish above; lower surfaces white, the outer parts of the pectorals gray. (Illustration after Norman, 1937: 436 mm.)

Size: ? Grows to 460 mm. in length.

Study Materials: None.

References: See Norman, *Discovery Reports*, 16, 1937: 34, for latest résumé of references and synonymy.

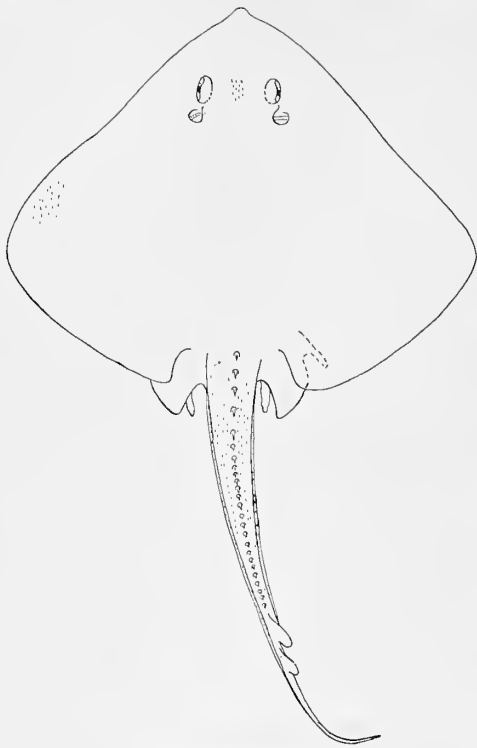
Psammobatus spinosissimus sp. nov.

(Plate II, Fig. 4).

Type: Holotype, embryo male taken from egg case, No. 6132, *Arcturus* Oceanographic Expedition, Department of Tropical Research, New York Zoological Society. Station 72:D-3 (4° 50' N., 87° 00' W.) sixty miles south of Cocos Island, June 3, 1925, in 765 fathoms; total length 248 mm., type in the collection of the Department of Tropical Research.

Measurements: (Percentages of the total length stated in parentheses). Total length 248 mm., disk length 115 mm. (46.5%), disk width 145 (58.5%), tail length 135 (54.5%), snout to mouth 27 (11%), snout to eye 23 (9.3%) snout to nostril 20 (8.1%), snout to end of pelvic fins 125 (50.5%), snout to vent 103 (41.5%), snout to 1st gill slit 47 (19%), interorbital space 23 (9.3%), internarial space 23 (9.3%), mouth width 21 (8.5%), space between 1st gill-slits 44 (17.8%), space between 5th gill-slits 30 (12.1%), eye 8 (3.2%), spiracle 5 (2%), eye + spiracle 12 (4.7%), 2nd dorsal fin to tip of caudal 39 (15.7%), snout to transverse line across disk at greatest width 72 (29%).

Description: Disk diamond-shaped, broader than long with its greatest width at a point 62% of the disk length from the snout; anterior



Text-figure 21.

margin with a conspicuous bulge in front of the eye; tip of snout produced into a small blunt nubbin, no indication of a barbel. Disk above and below covered thickly and evenly with small, recurved spines, extending to the tip of the snout and to the edge of the disk; these spines are somewhat more abundant in a round cluster between the eyes and on the forehead and snout; only the claspers and an area immediately around and behind the anus are free from spines. The first enlarged median spine occurs at the level of the inner, free margin of the pectorals about 110 mm. back of the snout. The spines increase gradually in size to the fifteenth, then are succeeded in a continuous unbroken line by a further series of ten, smaller, subequal and closer together, ending at the first dorsal fin. Tail covered everywhere with small spines, even over the surface of the dorsal fins. Tail with two well developed fin folds extending back along each side almost to the tail tip; a small, low filamentous fold along the dorsal surface of the tail beginning close behind the 2nd dorsal fin and extending to the tip of the caudal. Outer separated portion of the pelvics appearing like a thickened finger, similar in general shape and size to the clasper; the latter are 10 mm. in length. Superior oral velum low and smooth, with a short cluster of about a dozen fimbriae at each corner of the mouth. Teeth are only partly developed, small, flat-cusped, separate, numbering about thirty across the extent of the mouth.

Color in life uniform greenish slaty-gray both above and below, with the margins of the disk narrowly dusky. In the preserved fish, the color both above and below is pale brown with the outer border of the pectoral somewhat darker.

The weight of the embryo when first removed from the egg case was 170 grams.

Egg Case: This was olive green in color, and measured 160 mm. by 110 mm., by 43 mm. thick. The longest of the four tentacles was 100 mm. long.

Study Material: The type and only known specimen; Color Plate A950, and the egg case.

References: Deep Sea Ray, Beebe, W., *The Arcturus Adventure*, New York, 1926: fig. 32 (photograph of specimen and egg case).

Discussion: This species runs to *lima* in Norman's key to the genus but differs from that species in the distribution of spines on the dorsal and ventral surfaces, in the different size and shape of the spiracle, greater number of spines on the dorsal surface of the tail, and in the length of the tail posterior to the second dorsal fin (possibly the tip of the tail is broken off in most specimens of this genus; in our specimen, which was taken from an egg case, the caudal is long and tapering and has a filamentous fold on the upper surface).

Family DASYATIDAE.

Key to tropical eastern Pacific genera.

- 1a. Caudal fin absent.
 - 2a. Tail very long, whip-like.....*Dasyatis*.
 - 2b. Tail very small, much shorter than the disk.....*Gymnura*.
- 1b. Caudal fin present.
 - 3a. Caudal fin broad, convex posteriorly; tail somewhat shorter than the disk.....*Urobatus*.
 - 3b. Caudal fin narrow and pointed; tail longer than the disk.....*Urotrygon*.

Dasyatis Rafinesque, 1810.

Key to tropical eastern Pacific species.

- 1a. Tail with a keel or fold on its upper surface.
 - 2a. Tail with a keel above and a fold below.....*longus*.
 - 2b. Tail with folds both above and below.....*brevis*.
- 1b. Tail without keel or folds above; a low keel below.....*pacificus*.

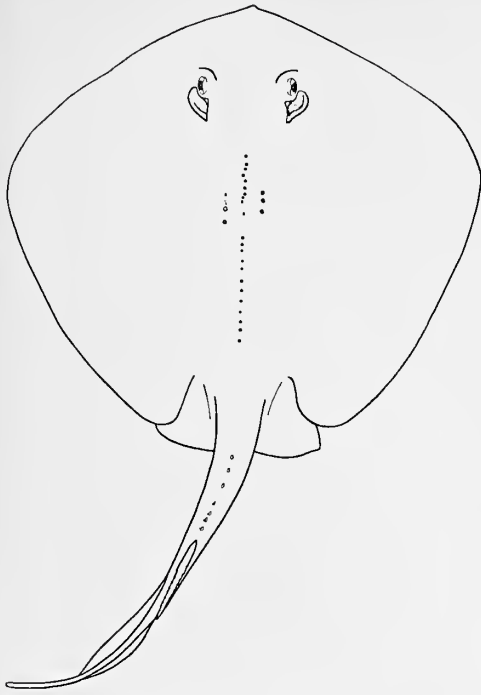
Dasyatis brevis (Garman).

Rat-tailed Ray; Kite-shaped Ray.

(Plate III, Fig. 1).

Range: San Diego south to Peru and the Galápagos Islands. (Mexico: San Francisquito Bay, Mulege, Inez Bay, La Paz; Costa Rica: Gulf of Nicoya; Peru: Payta, Paracas Bay).

Field Characters: Tail slender, longer than body when unbroken; a strong spine on tail; no dorsal or caudal fins, but a long, vertical fold of skin above and below the tail; disk kite-shaped, with greatest width two-fifths of disk length back of snout. (Illustration from specimen 24,995: 702 mm. long, 463 mm. snout to caudal spine base.)



Text-figure 22.

Color: Dark brown or black, unmarked.

Size and Weight: Six feet or more in length. A four-foot male weighed fifty pounds.

Food: A 27-inch female from Inez Bay had thirty or more small crabs in its stomach, all of the same species.

Study Material: 5 specimens. Mexico: Inez Bay, female (24,943), total length 1257 mm. (4 feet, 1½ inches), April 10, 1936, speared at night. Mexico: Inez Bay, male (24,995) total length 702 mm. (27½ inches), April 13, 1936, speared at night. Costa Rica: Gulf of Nicoya, 2 specimens, in collection of Museo Nacional, San Jose, Costa Rica; Galápagos Islands: Gardiner Bay, Hood Islands: female (5506), April 25, 1925, disk length 371 mm.

Dimensions: (In Percentage of Total Length.)

	Male (24,943)	Female (24,995)
Total length	1257 mm.	702 mm.
Disk length	53.5%	47.2%
Disk width	57	—
Tail length	58.4	52.8
Snout to mouth	9.8	7.8
Snout to eye	12.4	11.
Snout to anterior nostril	7.3	6.4
Snout to end of pelvics	57.	50.
Snout to 1st gill-arch	15.	14.3
Interorbital space	11.	10.2
Internarial	10.6	
Anterior internarial space	5.4	4.8
Mouth width	4.3	5.
Space between 1st gill-arches	13.3	11.
Space between 5th gill-arches	8.	7.

Vertebral spines:

Male: about 90; continuous from back of eye to tail spine.

Female: 25; continuous half way to tail, then 2 and 1.

Humeral spines:

Male: 15.

Female: 5.

Teeth of Male: Upper jaw: 11 straight rows, 20 oblique rows.

Lower jaw: 18 straight rows; 26 oblique rows.

Discussion: Our Galápagos Island specimen has strong dorsal spines, considerably stronger than is shown in the various figures of this species. The specimen has its tail broken; judging from similar sized specimens, its total length was about 40 inches. Probably the heavy spines are associated with its size and age.

References: *Trygon brevis*, Garman, S., *Bull. Mus. Comp. Zool.*, 6, 1879: 171 (original description; type locality, Payta, Peru?).

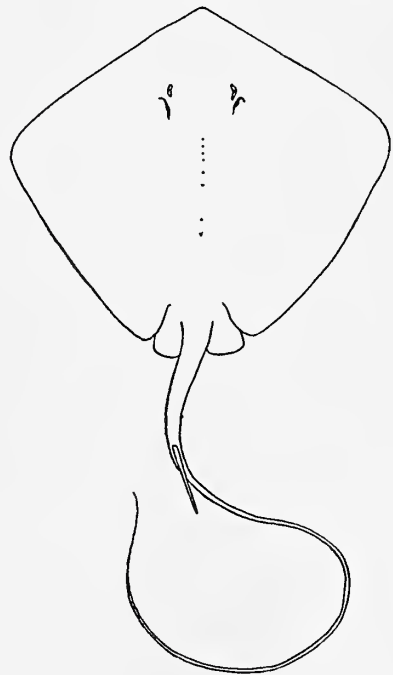
Dasyatis dipterurus, Jordan, D. S., & Gilbert, C. H., *Proc. U. S. Nat. Mus.*, 3, 1880 (1881): 31 (original description, type locality San Diego, California).

Dasyatis brevis, Garman, S., *The Plagiostomia*, 1913: 396, Plate 32, figs. 5, 6 (description; figure, Payta Peru). Breder, C. M., Jr., *Bull. Bingham Oceanogr. Coll.*, 2 (1) 1928: 1 (San Francisco Bay, Lower California).

Dasyatis dipterura, Osburn, R. C., & Nichols, J. T., *Bull. Amer. Mus. Nat. Hist.*, 35, 1916: 145 (Mulege, Lower California). Wales, J. H., *Copeia*, 1932: 163 (La Paz, Lower California).

Dasyatis brevis, Nichols, J. T., & Murphy, R. C., *Bull. Amer. Mus. Nat. Hist.*, 46, 1922: 504 (Paracas, Peru). *Ampholistius dipterurus*, Beebe, W., "Zaca Venture," 1938: 120, 301 (Santa Inez Bay, Lower California).

Dasyatus longus (Garman).



Text-figure 23.

Range: Gulf of California to the Galápagos. (Mexico: Mazatlan, Acapulco; Costa Rica: Port Parker; Panama: Panama Bay; Galápagos: Narborough, Hood Islands.)

Field Characters: Tail slender, from one and four-fifths to more than twice length of disk; a strong spine on tail; no dorsal or caudal fins, but a low keel above and a fold of skin beneath the tail; disk rhomboid, greatest width two-fifths back of snout; anterior margins of disk straight, snout not protruding; snout angle blunt, 117° ; spines along mid-back, and sometimes on interorbital and on tail. Color, uniform brown above. (Illustration after Garman, 1913, 1,000 mm.)

Size: A male seined at Port Parker, Costa Rica, measured in total length 2,574 mm. (8 feet, $9\frac{1}{2}$ inches) and weighed 102 pounds.

Abundance: Not a common ray, usually only single specimens have been captured in any one locality. An exception was at Port Parker, Costa Rica, where we seined two and saw eight more large individuals.

Study Material: 2 specimens, not saved; Port Parker, Costa Rica, both males; lengths, 2,574 and 1,769 mm., Jan. 21, 1938; seined.

Measurements: in percentages of total length.

	1st Specimen		2nd Specimen	
	mm.	%	mm.	%
Total length.....	2574		1769	
Disk length.....	978	38.4	660	37.3
Disk width.....	1162	45.6	787	44.5
Tail length.....	1854	72.7	1295	73.
Eye.....	21	.82		
Snout.....	241	9.4		
Interorbital.....	176	7.		
Internarial.....	110	4.3		
Snout to mouth....	228	8.9		
Mouth width.....	85	3.3		
1st to 5th gills....	146	5.7		
Length to base of tail	354	14.		
Base of tail to spine	406	16.	233	13.2
Spine length.....	160	6.3	150	8.5

Discussion: The characters of disk spines, oral papillae, and tail length are so variable, that if the caudal keel and fold of skin in an adequate series of specimens, prove to be also variable or sex characters, the two species *longus* and *brevis* should be merged.

References: Trygon *longa*, Garman, S., *Bull. Mus. Comp. Zool.*, 6, 1880: 170 (original description; type locality, Acapulco, Mexico, Panama). Jordan, D. S., & Gilbert, C. H., *Bull. U. S. Fish Comm.*, 2, 1882 (1883): 105 (Mazatlan, Mexico).

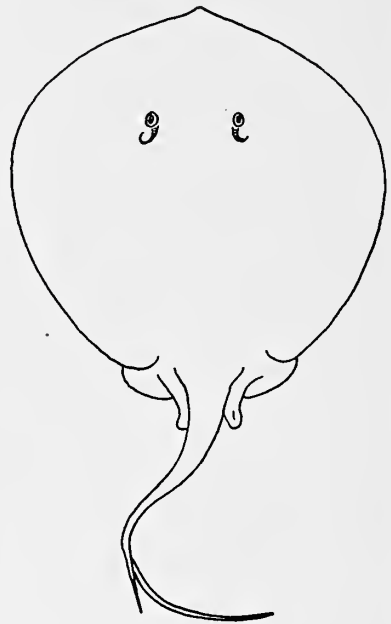
Dasyatis longus, Evermann, B. W., & Jenkins, O. P., *Proc. U. S. Nat. Mus.*, 14, 1892: 132 (notes on 4 specimens, Guaymas, Mexico). Jordan, D. S., *Fishes of Sinaloa*, 1895: 389 (common at Mazatlan).

Dasyatis longa, Gilbert, C. H., & Starks, E. C., *Fishes of Panama Bay*, 1904: 17, 207 (Panama, description). Snodgrass, R. E., & Heller, E., *Proc. Wash. Acad. Sci.*, 6, 1905: 345 (short description; numerous at Narborough Island, Galápagos).

Dasybatus longus, Garman, S., *The Plagiostomia*, 1913: 390, Plate 32, figs. 3, 4 (short description, figure). Meek, S. E., & Hildebrand, S. F., *Marine Fishes of Panama*, 1, 1923: 79 (description, Panama).

Dasyatis pacificus sp. nov.

(Plate II, Figs. 1, 2 and 3).



Text-figure 24.

Type: Holotype, male, No. 26,120, Department of Tropical Research, New York Zoological Society; Port Parker, Costa Rica, January 22, 1938, harpooned at night, total length 1,524 mm. Type in the collection of the American Museum of Natural History.

Field Characters: Tail slender, one and three-quarters times as long as length of disk; two strong caudal spines; no dorsal or caudal fins, but a low keel on the ventral side of the tail; disk sub-spherical with widest area two-fifths of distance back from snout; snout small but protruding beyond disk profile; snout angle blunt, 120 degrees; faint traces of double, dorsal cluster of somewhat enlarged tubercles; entire upper surface a hard armor of solid, low, radiating tubercles. Uniform brown above; white below with a broad border of dark.

Size: The two known specimens measure respectively 1,270 and 1,524 mm. in total length.

Description: Measurements, with percentage of total length (percentages in parentheses). Total length, 1,524 mm., disk length, 558 mm. (35.6); disk width, 622 mm. (41); tail length, 965 mm. (63.3); snout to eye, 132 mm. (8.7); snout to mouth, 110 mm. (7.2); snout to nostril, 90 mm. (5.9); snout to first gill-slit, 190 mm. (12.5); interorbital, 98 mm. (6.45); internarial, 50 (3.3); mouth width, 50 (3.3); eye, 13 mm. (.85);

spiracle, 45 mm. (2.95); interspace of first gill, 146 mm. (9.6); base of tail to first spine, 432 mm. (28.3); first spine length 73 mm. (4.8); second spine length, 135 mm. (8.85); space between base of spines, 50 mm. (3.3); gill-slit greatest length 26 mm.

Whole head and body covered with a mosaic of low, blunt, radiating tubercles. Slight suggestion of two shoulder clusters of slightly enlarged but blunt tubercles. The dorsal tubercles die out toward edge of disk, but become small, sharp spinules along rim of eyes and spiracles, and on distal portion of tail.

The surface of the skin shows a dense covering of separate tubercles. These average 1.4 mm. in diameter, with larger ones up to 2.8 mm. They show no pattern of arrangement, being about their own diameter apart. They are irregularly round, and composed except for a thin basal sheet of bone, of white enamel. From the center radiate four irregular ridges which in turn divide, especially near the margin. The skin between the tubercles is of a very tough, gristle-like character, adding to the tubercles in giving a feeling of solid hardness to the surface as a whole.

A low, infra-caudal keel begins at base of second spine and ends at vertical of tip of spine. Tail, halfway between base and base of first spine, 40 mm. wide, and 27 mm. deep.

Superior velum almost straight, fimbriated. Lower jaw outside, notched in center, thence curving backward on each side to the gape. Considerable area below and behind mouth strongly papillose.

Teeth: Dental area of lower jaw in general wavy, there being three curved depressions in the outer half, the inner half remaining flat and level. Width of this area 43 mm., front to back 15 mm. About 31 rows across, and 12 from front to back. Width of the teeth 1.7 mm. Each tooth has a deep base, stout, extending straight down but not attached to its neighbors. The summit is flat but projects slightly over the two in front, the teeth being staggered like tiles. A deep transverse groove extends across the center of each tooth, and the anterior, or interiorly pointing rim is curved. At the summit of this curve is a well-developed toothlet, almost level with the general surface of the whole area, but pointing down the throat. These small teeth are largest and sharpest among the innermost rows, gradually dying out because of wear as the exterior edge is approached. The edges of each tile tooth, around the central groove is strongly marked with minute ridges and flat cusps.

Five large papillae extend along the bottom of the inside of the mouth, blunt, thick and creased, the largest 8 mm. in height.

Color: Above uniform brown, with considerable dusky mottling on the posterior lobe of the pectorals. Below, creamy white, a border of dusky black beginning as an irregular series of mottlings at snout, and increasing in width and intensity backward to a maximum of 50 mm.,

continued on to the pelvics, and dying out rapidly on the postero-inner border. Claspers dominantly dusky; entire under tail black.

Local Distribution: Our specimens were harpooned in shallow water at night near shore.

Food: In the stomach of one were thirty snapping shrimps, squillas, and a few pieces of broken, strongly ribbed, cardium shells.

Study Material: 2 specimens; Port Parker, Costa Rica; male and female; only one specimen, the type, saved, No. 26,120; total length 1,270 and 1,524 mm.; Jan. 22, 1938; harpooned at night.

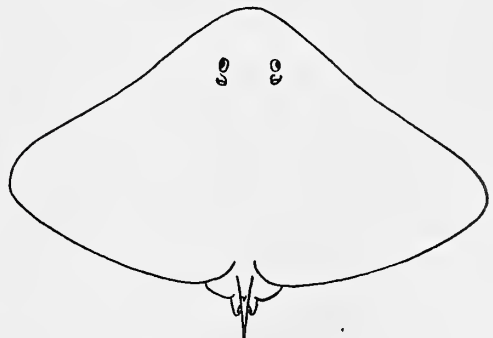
Discussion: The following differences are listed between this new species of *Dasyatus* from the Pacific, and *Dasyatus schmardae* from Jamaica and the Atlantic side of the Panama Canal, which is apparently its closest relative.

In our specimens the spiracles are almost three and a half (3.46) times the length of the eyes (not "more than twice the size of eyes"). The inter-orbital space is 1.24 in preocular snout (not 1.5). The longest gill-slit is 26 mm., twice the length of eye (not "gill-slits small, longest about the length of eye"). Dorsal humeral tubercles are flat and inconspicuous in specimen No. 1, and almost absent in No. 2 (not "two greatly enlarged tubercles or bucklers"). Two large caudal spines in both specimens (not a single caudal spine). Tail is almost round in front of first spine (not "tail notably depressed in advance of spine"). Color white below with wide black border (not "color pale underneath"). Teeth are pale and normally colored (not "teeth very dark"). Disk length into width in our specimens, one and one-tenth and one and one-fifth (not one and one-twentieth).

Notes: Our preparateur ran the spine of one of the rays into his hand, and almost fainted with the pain. It was relieved with hot water and strong epsom salts and after twenty-four hours the pain and swelling were almost gone.

Gymnura Van Hasselt, 1823.

Gymnura marmorata (Cooper).



Text-figure 25.

Range: San Diego to Peru (Mexico: Cedros Island, San Bartolome Bay, Felipe Bay, Gonzago

Bay, San Francisquito Bay, Mazatlan; Panama: Bay of Panama; Peru: Lobos de Afuera).

Field Characters: Disk almost twice as wide as long; tail very short, one-third length of disk; no dorsal or caudal fins, but a slight fold of skin above and below tail; skin perfectly smooth; tail spine very small or absent.

Color: The color and pattern show great variation; typical pattern, disk marked with both light and dark spots on a tan ground darkened by seal-brown dots; the light spots are pale, almost lemon yellow, surrounded by a brown edging; dark spots are vandyke-brown; pelvics are reddish-brown; tail is mottled, sometimes banded.

Size: Reaches a length of between four and five feet.

Abundance: Reported as very common at Mazatlan and elsewhere.

Study Material: None.

References: *Pteroplatea marmorata*, Cooper, J. G., *Proc. Calif. Acad. Sci.*, 3, 1863: 112, fig. 25 (original description, figure, type locality, San Diego, California). Jordan, D. S., & Evermann, B. W., *Fishes North and Middle America*, 1, 1896: 87 (short description, Point Concepcion to Cedros Island). Starks, E. C., & Morris, E. L., *Univ. Calif. Pub. Zool.*, 3, 1907: 173 (description, color, "Santa Barbara to San Bartolome Bay, Lower California"). Osburn, R. C., & Nichols, J. T., *Bull. Amer. Mus. Nat. Hist.*, 35, 1916: 145 (Port San Bartholome, Lower California). Breder, C. M., Jr., *Bull. Bingham Oceanogr. Coll.*, 2, 1928: 12, figs. 11, 12 (questions validity of *P. crebrispunctata* Peters and *P. rava* Jordan & Starks, color; Gulf of California: North of San Felipe Bay, San Francisquito, Gonzago Bay, figures). Kumada, T., & Hiyama, Y., *Marine Fish West Coast of Mexico*, 1937: 23, Plate 2 (short description, Plate).

Pteroplatea crebrispunctata, Peters, W. C. H., *Monatsber. Akad. Wiss.*, 1869: 703 (original description; Mazatlan, Mexico). Jordan, D. S. & Gilbert, C. H., *Bull. U. S. Fish Comm.*, 2, 1882 (1883): 105 (Mazatlan, Mexico). Jordan, D. S., *Fishes of Sinaloa*, 1895: 390 (description, color, common at Mazatlan, Mexico). Jordan, D. S., & Evermann, B. W., *Fishes of North and Middle America*, 1, 1896: 87 (description, "Gulf of California and southward"), Vol. 3, 1898: 2753 (amended description). Gilbert, C. H., & Starks, E. C., *Fishes of Panama Bay*, 1904: 18 (note on proportions, Panama). Garman, S., *The Plagiostomia*, 1913: 413 (short description, color). Evermann, B. W., & Radcliffe, L., *Bull. U. S. Nat. Mus.*, 95, 1917: 16 (description, color; Peru: Lobos de Afuera).

Pteroplatea rava, Jordan, D. S., & Starks, E. C., in Jordan, D. S., *Fishes of Sinaloa*, 1904: 390 (original description, color, type-locality, Mazatlan, Mexico; type No. 1587, Stanford University Museum). Jordan, D. S., & Evermann, B. W., *Fishes North and Middle America*, 3, 1898: 2754 (copy of original description).

Pteroplatea sp., Kumada, T., & Hiyama, Y., *Marine Fish Pacific Coast Mexico*, 1937: 23, Plate 57 (short description, figure).

Urotrygon Gill, 1863.

Key to species of the tropical eastern Pacific.⁶

- 1a. No enlarged spines or tubercles on the median line of the back; upper surface of the disk closely beset with short prickles, largest on the back.
- 2a. Length of disk about equal to width of disk. *mundus*.
- 2b. Length of disk 1.2 in width of disk. *binghami*.

⁶ This key, adapted and extended from that given by Meek & Hildebrand, (1923), should be used with great caution. The species of eastern tropical Pacific *Urotrygon* are poorly known from a small number of specimens, and in those species where a larger number of specimens have been taken, there is considerable variation. On the Eastern Pacific Expeditions only one specimen of the genus was taken; this helps very little in elucidating the problems of the species of the genus. As an aid to future students we give the original descriptions of each species, plus the references that refer to the eastern tropical Pacific.

1b. One to 8, or a continuous series of spines, on the median line of the back and the base of the tail (wanting in very young); skin smooth or less prickly.

3a. A *continuous* series of spines on the median line of the back, extending from shoulder to caudal spine; skin with short prickles. *asterias*.

3b. No *continuous* series of spines on the median line of the back; spines sometimes present in a group on the middle of the back, or on the tail.

4a. One to three strong spines on the middle of the back.

5a. Spines present on the tail immediately before the caudal fin. *chilensis*.

5b. No spines on the tail before the caudal fin. *goodei*.

4b. No sharp spines on middle of back; one to 9 sharp spines at base of tail in advance of caudal spine; skin smooth. . . *aspidurus*.

Urotrygon aspidurus (Jordan & Gilbert).

Range: Panama Bay.

Copy of original description: "Color plain brown; upper side of body and tail white.

"Disk very slightly longer than broad, its length very little less than length of tail; anterior margins of disk nearly straight, the anterior tip abruptly projecting as an exerted, narrow, triangular prominence rounded at its end; length of exerted part about as long as the width of its base, and from half to two-thirds the interorbital width, it being longer and sharper in a male specimen, in which also the anterior margins of the disk form a less obtuse angle; distance from eye to tip of snout about one-third length of the disk. Eyes very small, much smaller than the large spiracles, their diameter less than half interorbital width. Width of mouth $2\frac{1}{2}$ in distance to tip of snout. Nostrils directly in front of mouth; nasal folds forming a broad continuous flap, the edges of which are slightly fringed. Ventrals projecting a little beyond outline of disk. Caudal spine very large, its length a little more than twice interorbital width (in a large female specimen duplicated, and as long as from eye to tip of snout), its insertion well in front of middle of tail. Caudal fin long and low, the lower portion longer, beginning nearly opposite tip of caudal spine. Depth of tail with the caudal fin, about half interorbital width.

"Skin entirely smooth, with the exception of a series of strong broad-rooted spines or bucklers on the upper part of the tail in front of caudal spine, and sometimes a series of minute sand-like prickles on snout, and on median line of body. These latter are present only in a large female specimen, which also has 8 spines on the tail instead of 2 as in the others. These spines are straight, sharp, directed backwards, their height about equal to width of base which is somewhat longer than diameter of pupil.

"This species is not uncommon in the Bay of Panama, and is brought into the market in company with *Urolophus mundus*. Three speci-

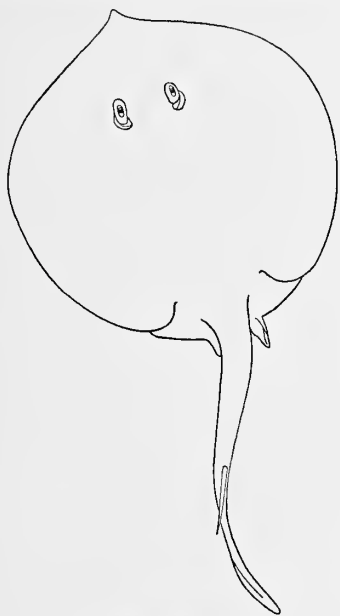
mens were obtained, the largest about 18 inches in length."

Gilbert & Starks (1904, p. 16) made corrections and additions to this description and described embryos, and Garman (1913, p. 405) speaks of the relationship of *U. chilensis* to this species.

References: *Urolophus aspidurus*, Jordan, D. S., & Gilbert, C. H., *Bull. U. S. Fish Comm.*, 1, 1881 (1882): 306, 307 (original description, type locality, Panama Bay). Gilbert, C. H., & Starks, E. C., *Fishes of Panama Bay*, 1904: 16 (description, adult and embryos, Panama Bay, abundance). Garman, S., *Bull. Mus. Comp. Zool.*, 46 (12) 1906: 229 (Panama). Kendall, W. C., & Radcliffe, L., *Mem. Mus. Comp. Zool.*, 35 (3) 1912: 80 (Panama Bay).

Urotrygon aspidurus, Garman, S., *The Plagiostomia*, 1913: 405, Pl. 69 (numerous specimens, Panama; "Hardly to be separated from *U. chilensis* Günther, 1871," figure of skeletal cartilages).

Urotrygon asterias (Jordan & Gilbert).



Text-figure 26.

Range: Mexico and Panama. (Mexico: Mazatlan, Acapulco, and "west coast of Mexico"; Panama: Bahia Honda, Naos Island, Panama Bay.) (Illustration after figure of *U. mundus*, Garman, 1913, 210 mm.)

Copy of original description of U. asterias: "Disk almost round, a little broader than long; its length just about equal to length of tail. Anterior margins of disk nearly straight, the tip acute, slightly exserted, much less prominent than in *U. aspidurus*, longer in the male specimen than in the females. Distance from eye to tip of snout, about one-fourth length of disk and a little more than twice interorbital width. Interorbital space somewhat concave. Eyes small, much smaller than the large spiracles, the diameter about half the interorbital width. Width of mouth $2\frac{1}{6}$ in distance from tip of snout. Teeth conic and sharp in the males, blunter and somewhat pavement-like in the females. Nostrils

directly in front of angles of mouth; nasal folds forming a broad continuous flap, the edges of which are slightly fringed.

"Ventrals projecting a little beyond outline of disk. Caudal spine very long, somewhat longer than snout, its insertion considerably in front of middle of tail. Caudal fin moderate, the upper lobe deepest, inserted opposite tip of caudal spine, the lower lobe beginning farther forward, the depth of the tail with caudal fin, about half the interorbital space.

"Skin above everywhere rather sparsely covered with small stellate prickles, these larger and more numerous toward the median line of the back and head; wanting on the ventral fin. Males and females about equally rough. Median line of back with strong, sharp recurved spines, 18 to 32 in number, extending from the shoulders to the front of the caudal spine, these usually becoming much larger and sharper backward, but the largest much smaller than the spines in *U. aspidurus*.

"Color, light brown, without distinct markings; tail, faintly edged with dusky; lower side white.

"This species is not rare at Mazatlan, where it is known as *Raia*. It is also occasionally taken at Panama.

"Three females and one male specimen, from 12 to 16 inches in length, were brought from Mazatlan, and one young male from Panama."

Copy of original description of Urotrygon rogersi: "Disk broader than long by a distance two and a half times the interorbital width; anterior margins of disk nearly straight, the tip of snout projecting; snout from eye three and three-quarters in length of disk; eyes little smaller than spiracles; width of mouth two and a half times in preoral part of snout; caudal spine inserted in front of middle of tail. Skin with minute prickles on margin of pectorals and on middle of back, leaving smooth areas near middle of pectorals and over branchial arches; 16 to 20 large spinules along median line of back and tail. Color, plain brown; caudal fin darker, edged with white.

"This species differs from *Urolophus asterias* in having a wider disk, more acute snout, much smaller prickles, and fewer spinules on back and tail.

"Three specimens obtained in the Astillero (Mazatlan), the longest is 18 inches in entire length."

Concerning this type which is in the collection of Stanford University, Dr. G. S. Myers writes as follows:

"The holotype of *Urolophus rogersi* is a female with the following present dimensions; total length 430 mm.; width of disk 280; snout tip to end of pelvic 238; tail length from anus 220; interocular 28; snout, left orbit to tip 68; between lower angles naso-labial flaps 25 mm."

The single small specimen of *Urotrygon* in our collection seems to fit best in this species.

Study Material: 1 specimen; seven miles west of Champerico, Guatemala; Station 197:D-2, 14 fathoms, Dec. 15, 1937, male, total length 148 mm., Cat. No. 27,520.

Disk almost circular, anterior margins straight, snout considerably produced; tail from base to spine strongly depressed; claspers developed well beyond pelvics; disk above generally but rather sparsely covered with very fine, sharp spines, especially abundant near, and actually along edge of anterior margins (except along extreme snout), on head and around eyes; these spines are almost absent from mid-back area, of mid-disk to tail; a series of low, blunt spinules, just visible above skin, from base of tail to spine, with numerous small spines down sides of tail, and generally over dorsal surface; dorsal portion of caudal fin with two lateral rows of spinules, and an irregular row near and along dorsal edge; ventral portion of caudal fin smooth; disk below smooth, but marginal spines visible. Caudal spine long and slender; the tip for an extent of 2 mm. is smooth; this is followed by about 18 strong, sharp barbs, extending for half the total length of the spine. Teeth in about twenty transverse rows, each with a wide, transverse base, and a tall, slightly tapering, stout cusp, curved slightly backward; two small, reserve teeth lying obliquely at the posterior base of each erect tooth. Anterior oral velum with about thirty-five papillae. Eyes very small, black.

Measurements: Percentages in total length; total length, 148 mm., disk length, 75 mm. (50.7); disk width 83 mm. (56); tail length, 80 mm. (54); base of tail to spine, 30 mm. (20.2); snout to eye, 26 mm. (17.6); snout to mouth 22 mm. (14.9); snout to nostril, 18 mm. (12.2); snout to 1st gill, 35 mm. (23.6); interorbital, 11 mm. (7.4); internarial, 10 mm. (6.75); mouth width, 9 mm. (6); eye, 2 mm. (1.35); spiracle, 2.9 mm. (1.95); interspace of 1st gills, 21 mm. (14); interspace of 5th gills, 18 mm. (12.2); spine length, 29.3 mm. (19.7). Teeth: base width .43; cusp height .23; height whole tooth .3 mm. Tail: half way between base and spine, 7 mm. wide and 4.4 mm. deep.

Color: Uniform dark buffy-brown above; white below.

References: *Urolophus asterias*, Jordan, D. S., & Gilbert, C. H., *Proc. U. S. Nat. Mus.*, 5, 1882 (1883): 579 (original description, Mazatlan and Panama). Jordan, D. S., *Fishes of Sinaloa*, 1895: 388 (Mazatlan, Mexico, very common). Kumada, T., & Hiyama, Y., *Marine Fish West Coast Mexico*, 1937: 22, Plate 56 (brief description, figure).

Urotrygon asterias, Meek, S. E., & Hildebrand, S. F., *Marine Fishes of Panama*, 1, 1923: 83 (description of adults and embryos, discussion). Breder, C. M., *Bull. Bingham Oceanogr. Coll.*, 2 (1), 1928: 11, fig. 8 (Bahia Honda, Panama; figure).

Urolophus mundus, Gilbert, C. H., & Starks, E. C., *Fishes of Panama Bay*, 1904: 16 (Panama; not of Gill).

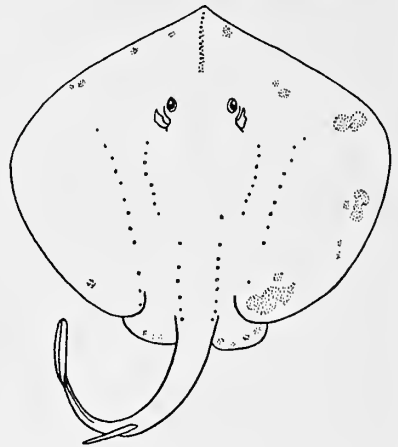
Urotrygon mundus, Garman, S., *The Plagiostomia*, 1913: 406, Plate 30, figs. 1, 2 (in part).

Urolophus rogersi, Jordan, D. S., & Starks, E. C., in Jordan, D. S., *Fishes of Sinaloa*, 1895: 388 (original description; type locality Mazatlan, Mexico; type No. 1700, Stanford University Museum). Kendall, W. C., & Radcliffe, L., *Mem. Mus. Comp. Zool.*, 35, 1912: 80 (short description, Acapulco, Mexico).

Urolophus sp., Kumada, T., & Hiyama, Y., *Marine Fish Pacific Coast of Mexico*, 1937: 22, Plate 56, fig. B. (figure).

Discussion: The figure of Kumada & Hiyama is included in the species principally because of the statement in Meek & Hildebrand (1923: 83) that the "wing-like expansion is proportionately greater in the adult than in the young."

Urotrygon binghami Breder.



Text-figure 27.

Range: Mouth of Colorado River, Gulf of California, in 10–14 fathoms.

Copy of original description of Urotrygon binghami: "Type No. 1019 Bingham Oceanographic Collection. Total length 190 mm.

"Disk somewhat angular; broader than long, length 1.2 in breadth; the anteriolateral margins slightly convex to directly in front of eyes where they become concave to meet at the rather produced tip of snout; the postero-lateral margins strongly convex; interorbital space 2.2 in preocular part of snout; spiracles a little larger than eyes and placed immediately behind them; mouth slightly curved, 2.7 in preocular part of snout; teeth pointed, small, diamond shaped; tail somewhat shorter than disk, 1.2 in disk; caudal fin low and long, pinnaform, extending on tail, 2.7 measured from tip to vent; spine inserted a little more than an eye's diameter nearer to vent than to tip of tail; tail strongly depressed, but with no lateral keels; ventral fins broad, with posterior margins continuing curve of pectorals; skin smooth, no distinct prickles anywhere but with small light points that suggest the possible development of them at a greater size. See Figures 6 and 7.

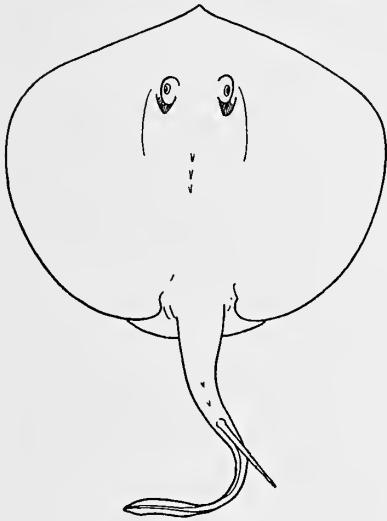
"Coloration—Nearly uniform grayish tan above, light below with numerous sub-dermal dark splotches. Caudal fin dusky, edged with light. There are a few light dots on snout and wings and a few dark blotches irregularly placed.

"This form is closest to *U. mundus* Gill but differs prominently in the much broader disk, the shorter tail, the more prominent snout, the curve of the ventrals and in other minor details. It

also differs from *U. mundus* in the lack of prickles, which, however, it may develop at greater size and from *U. asterias* (Jordan & Gilbert) in the lack of a median row of spines which would surely be evident at this size." (Illustration after Breder, 1928, 190 mm.)

References: *Urotrygon binghami*, Breder, C. M., Jr., *Bull. Bingham Oceanogr. Coll.* 2 (1), 1938: 11, figs. 6, 7 (original description, figures; type-locality, between San Felipe and Shoal Point, Rio Colorado; type No. 1019, Bingham Oceanogr. Coll., Yale University).

Urotrygon chilensis (Günther).



Text-figure 28.

Range: Chile (extralimital).

Copy of original description: "Disk broader than long; snout a little projecting; tail longer than the disk. Disk smooth, but with spines along the median line, viz., three in a single series in the middle of the back, and two on the tail, in front of the serrated spine. No rudimentary dorsal fin. Upper parts nearly uniform brownish, with a few very indistinct darker specks.

"Distance of the extremity of the snout from the vent— $4\frac{1}{2}$ inches.

"Distance of the extremity of the tail from the vent— $5\frac{3}{4}$ inches.

"Greatest width of the disk— $6\frac{1}{2}$ inches.

"One example from the Geoffroy Museum, is in the collection of the British Museum."

The description by Garman (*Plagiostomia*, 1913: 405) is practically identical with the above. He adds however, "Günther's figure so closely represents the species later described as *U. aspidurus*, differing mainly in the anterior position of some of the tubercles, as to raise doubt of the validity of that species." (Illustration after Günther, 1871, 255 mm.)

Reference: *Urolophus chilensis*, Günther, A., *Proc. Zool. Soc. London*, 1871: 653, Plate 53 (original description, figure, type-locality, Chile).

Urotrygon chilensis, Garman, S., *The Plagiostomia*, 1913: 405 (description; possibility of *U. aspidurus* being the same as *chilensis*).

This description of this extralimital species is included because of Garman's note as to its relationship to *aspidurus*.

Urotrygon goodiei (Jordan & Bollman).

Range: Panama and Ecuador. (Panama: 10 miles S. of Pearl Islands; Ecuador: St. Helene Bay).

Copy of original description: "Diagnosis.—Approaching *Urolophus halleri* and *nebulosus*, from which it is separated by the presence of a strong spine on the middle of the back, by the more angular outline, the narrow ventrals, and the plain coloration.

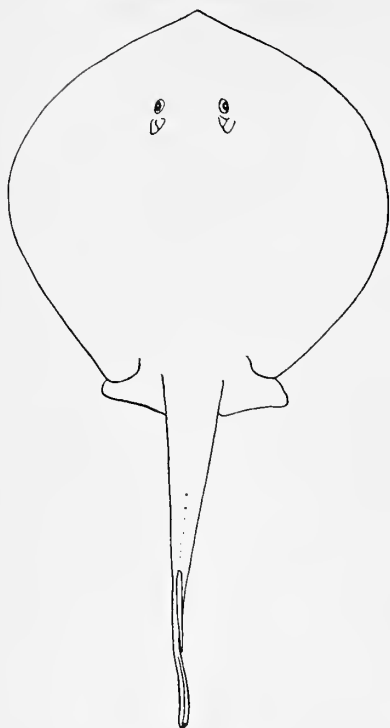
"Type: No. 41,150, U. S. National Museum.

"Hab.—Pacific Ocean, off coast of Colombia: $8^{\circ} 06' N.$, $78^{\circ} 51' W.$

"Description.—Disk (to posterior base of pectorals) broader than long by a distance equal to snout and half eye; anterior margins of disk very slightly convex from in front of eyes outwards. Snout with its tip exerted and sharply pointed, its length $3\frac{3}{4}$ in disk to base of pectorals. Eye about equal to spiracle, $3\frac{1}{4}$ in snout. Margin of spiracles not denticulated. Interorbital area scarcely concave, its width 2 in snout. Width of mouth 2 in preoral part of head. Nasal fold concave behind, its edge fringed. Ventrals projecting considerably beyond disk, their length (from anterior margin of vent backwards) $1\frac{1}{4}$ in their breadth. Caudal spine large, its length equal to snout and half eye, its margin with 8–10 sharp forward-projecting spinules; its insertion anterior to middle of tail measured from pectorals, its tip reaching front of caudal. Caudal fin (measured from end of spine) equal to snout and eye. Length of tail greater than that of disk by a distance equal to eye and spiracle. Body (in young specimens) entirely smooth except for the presence of one (or two) sharp spine on middle of back. Color plain brown, paler toward margins of disk; no spots or distinct markings; under side not mottled; caudal dark above, margined with pale.

"The above description was taken from a young female specimen 7 inches long. This specimen has the snout wholly smooth. Another, about an inch shorter has two spines on middle of back and the snout prickly. Both specimens were dredged at Station 2795, with the preceding species. The snout is wholly smooth in the type."

References: *Urolophus goodiei*, Jordan, D. S., & Bollman, C. H., *Proc. U. S. Nat. Mus.*, 12, 1889 (1890): 151 (original description, type locality, Albatross station 2795, $8^{\circ} 06' 30'' N.$, $78^{\circ} 51' W.$, 10 miles south of Pearl Islands, Bay of Panama, in 33 fathoms; type No. 41,150, U. S. Nat. Mus.). Boulenger, G. A., *Boll. Mus. Univ. Torino*, 13, 1898: 1 (St. Helene Bay, Ecuador).

Urotrygon mundus Gill.

Text-figure 29.

Range: Mexico, Costa Rica, Panama. (Mexico: Port San Bartholome, Estaban Island; Costa Rica: Puntarenas; Panama: Panama.)

Copy of original description: "The disk is orbicular with a slight linguiform projection in front and with the pectoral fins behind broadly rounded. The distance of the snout from the hinder margin of the pectorals equals the width of the disk. The tail (behind the anus) is rather longer than the body (in front). The spine is inserted behind the middle of the tail, and is about as long as the distance between the snout and the nostrils. The ventral fins extend outwards, the rectilinear anterior margin tending little backwards, and the external margins are on a line with and complete the outline of the disk. The posterior margin in the male is nearly rectilinear, while in the female it is slightly convex, especially towards the inner angles. The upper velum is very sinuous and fimbriated. The teeth are pointed and pyramidal. The spiracles are oval, interrupted at the inter-anterior angle by the eyes, and the margins are entire and well defined. The skin is beset with numerous, small, stelliform tubercles, larger on the dorsal region. The color is a uniform dark brown above.

"Two small specimens, male and female, are in the collection.

"The present species would, by many zoolo-

gists, be referred to the genus *Urolophus* of Muller and Henle, but it would appear that it and the *U. torpedinus* should be separated from that genus and referred to a distinct one, distinguished by the rounded and not angular outline, the longer tail and posterior insertion of the spine, and especially the acute teeth." (Illustration after Meek & Hildebrand, 1923, 220 mm.)

U. asterias and *U. rogersi* have been synonymized under this species. Meek & Hildebrand, however, give evidence to show that *asterias* and *mundus* are distinct.

References: *Urotrygon mundus*, Gill, T., *Proc. Acad. Nat. Sci. Phila.*, 1863: 173 (original description; type locality Panama; type lost). Garman, S., *The Plagiostomia*, 1913: 406, Plate 30 (in part; plate). Osburn, R. C., & Nichols, J. T., *Bull. Amer. Mus. Nat. Hist.*, 35, 1916: 145 (Lower California; Port San Bartholome, Estaban Island). Fowler, H. W., *Copeia*, 39, 1917: 3 (Costa Rica: Puntarenas). Meek, S. E., & Hildebrand, S. F., *Marine Fishes of Panama*, 1, 1923: 82, Plate 4 (description, color, figure; not identical with *asterias*).

Urolophus mundus, Jordan, D. S., & Evermann, B. W., *Fishes North and Middle America*, 1, 1896: (short description). Jordan, D. S., & Evermann, B. W., *Fishes North and Middle America*, 3, 1898: 2752 (statement that *mundus* and *asterias* are identical). Gilbert, C. H., & Starks, E. C., *Fishes of Panama Bay*, 1904: 16 (comments on identity of *asterias*, *mundus* and *rogersi*; see under *asterias*).

Urobatis Garman, 1913.

Key to tropical eastern Pacific species.

- 1a. Ashy gray, or brown, spotted conspicuously with black or dark brown *maculata*.
- 1b. Brown in general color, not spotted with black.
 - 2a. Brown with large pale spots, the darker interspaces forming reticulations, two narrow pale bands around the whole disk. *concentricus*.
 - 2b. Plain brown, or with yellow dots and vermiculations, no pale lines around the disk. *halleri*.

Urobatis concentricus Osburn & Nichols.

Reticulated Round Ray.

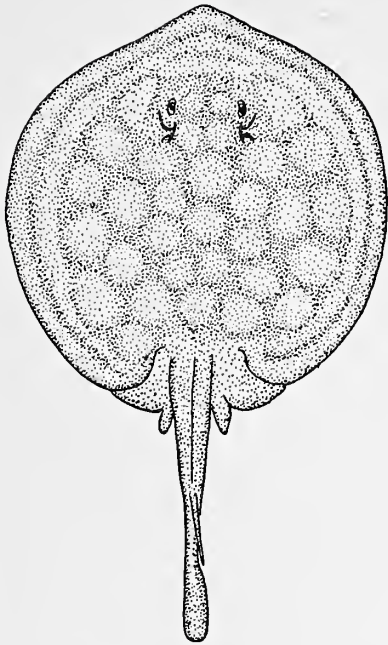
(Plate III, Fig. 2).

Range: Gulf of California south to southern Mexico. (Mexico: San Estaban Island, Inez Bay, San Lucas Bay, Port Guatulco.)

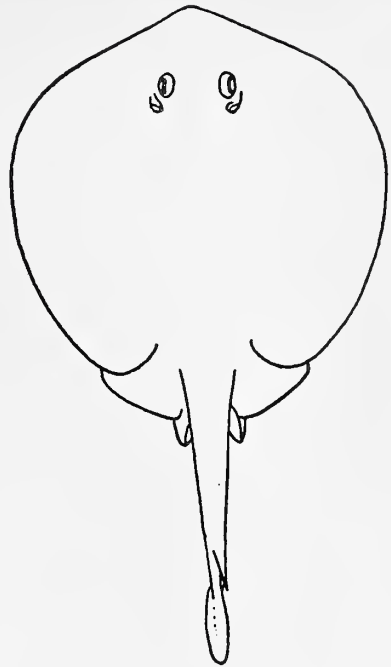
Field Characters: Disk outline round; no dorsal fins but a well-developed caudal fin; skin smooth; a strong caudal spine; tail shorter than disk; color dark, with large, rounded, pale spots, and with two pale lines bordering the disk. (Illustration from specimen No. 26,142, 385 mm.)

Color: The ground color is dark brown, broken everywhere into coarse reticulations by large, rounded, pale spots. They are arranged in two or three irregular rows around the mid-line of the disk, but they are different in each individual. Two, narrow, pale, unbroken bands, concentric with these spots, surround the outer area of the entire disk and extend on to the pelvis. Under side pale.

Size: The largest ray thus far recorded is a male taken by us at Inez Bay, with a total length of 475 mm.



Text-figure 30.



Text-figure 31.

Local Distribution: All our specimens were speared at night in shallow water.

Abundance: In Inez Bay we found these the most abundant of the smaller rays.

Food: Three individuals taken at Inez Bay had been feeding exclusively on small crabs. Two others had eaten polychaete worms.

Breeding: The females, measuring from 325 to 400 mm., had fully developed ovaries but no signs of eggs or young.

Study Material: 13 specimens; Mexico, Inez Bay, 11, 6 males, 5 females (24,999) 204 to 475 mm., April 13 to 16, 1936, speared at night. San Lucas Bay, female, (not saved) 460 mm. April 23, 1936, speared at night. Port Guatulco, female (26,042, Photo. 8537) 385 mm., Dec. 3, 1937, speared at night.

References: *Urobatis concentricus*, Osburn, R. C., & Nichols, J. T., *Bull. Amer. Mus. Nat. Hist.*, 35, 1916: 144, fig. 2 (original description, color; type locality San Esteban Island, figure, type No. 5199, Amer. Mus. Nat. Hist.).

Discussion: The only other recorded specimens are the type and three other individuals taken by the *Albatross*, at Esteban Island, in the Gulf of California on April 13, 1911. They were all males, and measured from 369 to 432 mm.

Urobatis halleri (Cooper).

Little Round Sting Ray.

Range: San Diego to Panama Bay (Mexico: Todos Santos Bay, San Francisquito Bay, Mazatlan, Colima, Acapulco; Panama: Panama Bay).

Field Characters: Disk outline round; no dorsal fins but a well-developed caudal fin; skin smooth; strong spine; tail shorter than disk; total length twenty inches or less. Color plain dark brown, or with numerous minute dots, or in female with a few dark spots. (Illustration after Starks, 1918.)

Color: Variations in a lot of one hundred specimens; "Most are brown with small spots of yellow, very small on some, larger on others, smaller toward the margins, thickly strewn over the entire back and tail. Less common variation are the brown ones with the yellow in the form of vermiculations. Some are more yellow than brown." (Garman, 1913.)

Size: The largest ray recorded is 521 mm. in length.

Local Distribution: These rays are found lying on the bottom, nearly buried in loose sand or mud.

Abundance: In places the shallow waters are said to be almost lined with these small rays, which are very dangerous to fishermen.

Food: Said to scoop out large holes in mud banks by waving the pectoral fins, eating the worms, crabs and small fishes thus exposed.

Breeding: Ovoviviparous; mating taking place in April, and the young, one to eight in number, are born in late July or August. Starks & Morris say that two embryos, nearly three inches long, taken from the oviduct, have a conspicuous flap extending back from the eye and upper edge of spiracle, and ending in a long, free point behind.

Study Material: None.

References: *Urolophus halleri*, Cooper, J. G., *Proc. Cal. Acad. Sci.*, 3, 1863: 95 (original description, San Diego, California). Jordan, D. S., & Gilbert, C. H., *Bull. U. S. Fish Comm.*, 2, 1882: 105 (Mazatlan, Mexico). Jordan, D. S., & Gilbert, C. H., *Proc. U. S. Nat. Mus.*, 5, 1882 (1883): 621 (Panama). Jordan, D. S., & Evermann, B. W., *Fishes North and Middle America*, 1, 1896: 80 (short description, color). Gilbert, C. H., & Starks, E. C., *Fishes of Panama Bay, 1904*: 15 (notes). Starks, E. C., & Morris, E. L., *Univ. Calif. Publ. Zool.*, 3 (11) 1907: 172 (color, embryos). Wilson, C. B., *Proc. U. S. Nat. Mus.*, 35, 1909: 447, 448 (copepod parasite). Kendall, W. C., & Radcliffe, L., *Mem. Mus. Comp. Zool.*, 35 (3) 1912: 80 (Acapulco, Mexico). Wilson, C. B., *Proc. U. S. Nat. Mus.*, 64 (17) 1925: 11 (parasitic copepod). Kumada, T., & Hiyama, Y., *Marine Fish Pacific Coast Mexico, 1937*: 22, Plate 55, fig. A. (short description, part, figures of female only).

Urolophus nebulosus, Garman, S., *Proc. U. S. Nat. Mus.*, 8, 1885 (1886): 41 (original description, comparison with *halleri*; Colima, Mexico, type No. 7356, U. S. Nat. Mus.). Evermann, B. W., & Jenkins, O. P., *Proc. U. S. Nat. Mus.*, 14, 1891 (1892): 132 (similarity to *halleri*, color, embryos, measurements, Guaymas, Mexico); Jordan, D. S., & Evermann, B. W., *Fish North and Middle America*, 1, 1896: (description, "replacing *halleri* southward"); Gilbert, C. H., & Starks, E. C., *Fishes of Panama Bay, 1904*: 15 (no authentic record for Panama).

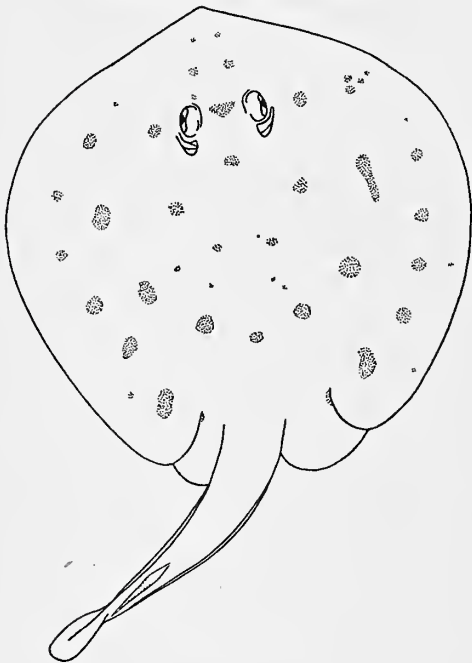
Urobatis halleri, Garman, S., *The Plagiostomia, 1913*: 403 (description, color variation in one hundred specimens). Meek, S. E., & Hildebrand, S. F., *Marine Fishes of Panama, 1, 1923*: 86 (comment on absence of recent Panama records, copy of Jordan & Evermann des., and of Garman's comments on color). Breder, C. M., Jr., *Bull. Bingham Oceanogr. Coll.*, 2 (1) 1928: 12, fig. 10 (San Francisquito Bay, Gulf of California; figures). Barnhart, P. S., *Marine Fish So. Calif.*, 1936: 14, fig. 38 (ecological notes, figure).

Urolophus umbrijer, Jordan, D. S., & Starks, E. C., in Jordan, D. S., *Fishes of Sinaloa, 1895*: 389 (original description; Mazatlan, Mexico).

Urobatis nebulosus, Garman, S., *The Plagiostomia, 1913*: 403 (short description).

***Urobatis maculatus* Garman.**

Spotted Round Sting Ray.



Text-figure 32.

Range: Gulf of California (Mexico: San Felipe Bay, Gonzago Bay, San Francisquito Bay, Inez Bay).

Field Characters: Disk outline round; no dorsal fins, but a well-developed caudal fin; skin smooth; a strong caudal spine; tail shorter than disk; color, light brown with fifteen to thirty small, round, black spots scattered over disk, all smaller than eye. (Illustration from specimen No. 25,265, 247 mm.)

Color: Light brown or ashy gray with many small dots of black, chiefly marking the openings of the lateral line system tubules; also a series of small dots along the sides of the tail, and on for a short distance along the disk; in some specimens a series of dots forming triangles along the inner edge of the pectorals. The dominant pattern is formed by a scattering of fifteen to thirty larger spots of black, all smaller than the eye, arranged in about three concentric lines around the disk, or so irregularly that this pattern is lost; below, creamy white.

The colors of a fresh specimen, a male, 400 mm. long, as sketched by an artist, are given by Breder as follows: "The disk is edged by a reddish brown becoming lighter posteriorly and deepening anteriorly to a chocolate on the entering angle. Inside of this and parallel to the edge runs a broken vandyke-brown band, darkest and widest across the snout. The central part of the disk is lighter and variously mottled with light tan, pale slate, and greenish-brown. The claspers are purplish and the caudal base anterior to the spine, is similarly suffused. Posterior to the spine and on the fin proper there is a slightly bluish cast. Below, the central part of the disk is a very pale tan and a faint olive tint."

Size: The largest ray of this species measured 420 mm. in length.

Dimensions: (in percentage of total length).

	Male 24,997	Female 25,265	Female 25,265a
Total length.....	272 mm.	247 mm.	270 mm.
Disk length.....	55%	59.5%	54.5%
Disk width.....	58	58.7	55.6
Tail length.....	46.5	50	45.6
Snout to mouth.....	12.5	12	12
Snout to eye.....	14.7	13.8	11
Snout to nostril.....	10.2	9.7	9.25
Snout to end of pelvics...	63.5	62	61
Snout to 1st gill-slit.....	22.4	21.9	21
Interorbital.....	5.9	5.7	5.5
Internarial.....	5.9	6	5.2
Mouth width.....	6.6	6.5	6.3
Space between 1st gill-slits	14.3	11.3	14
Space between 5th gill-slits	9.2	8	9

Food: Six individuals had been feeding on large polychaete worms, *Leodice* sp., and a scattering of amphipods.

Study Material: 4 specimens. Mexico: Santa Inez Bay, two males, two females (24,997, 25,265, 25,265a), length 242 to 276 mm., April 13 to 16, 1936. Spared at night.

References: *Urobatis maculatus*, Garman, S., *The Plagiostomia, 1913*: 404 (original description, Gulf of California). Breder, C. M., Jr., *Bull. Bingham Oceanogr. Coll.*, 2 (1) 1928: 12 (color; San Felipe Bay, Gonzago Bay, San Francisquito Bay); Beebe, W., "Zaca Venture, 1938: 120, 300 (Santa Inez Bay, Gulf of California). *Urolophus halleri*, Kumada, T., & Hiyama, Y., *Marine Fish West Coast Mexico, 1937*: 22, part; Plate 55, fig. B (description, in part, figure).

Discussion: Kumada & Hiyama's figure of the supposed male of *U. halleri* is identical with a male in our collection here assigned to *maculatus*. We have similarly patterned males and females of *maculatus*.

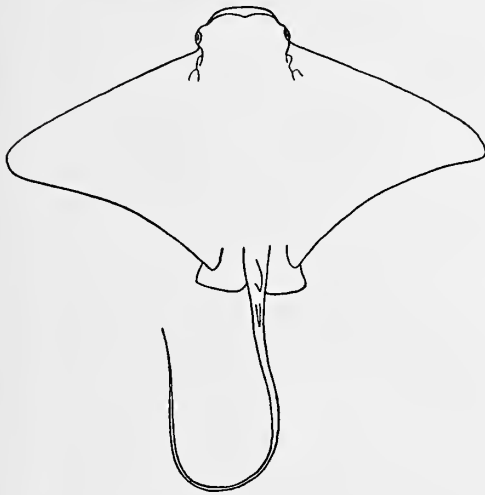
Family AETOBATIDAE.

Key to tropical eastern Pacific genera.

- 1a. Teeth pavement-like, forming a flattened plate; more than three rows in each jaw, the central row much wider than the others.
- 2a. Side of head not free from the pectoral fins; upper surface of body and wings uniformly colored, without spots or bands. *Aetobatis*.
- 2b. Sides of the head free from the pectoral fins; upper surface of body and fins with white bands and spots. *Pteromylaeus*.
- 1b. Teeth pavement-like, forming a flattened plate; in a single row in each jaw; upper surface of body with white spots. *Stoasodon*.

Aetobatus Blainville, 1816.⁷

Aetobatus californicus (Gill).



Text-figure 33.

Range: Cape San Mendocino, California, south to Magdalena Bay, Lower California (Mexico: Port San Bartholome, Turtle Bay, Santa Maria Bay).

Field Characters: Large rays with pointed pectoral fins; tail whip-like without a caudal fin; a single dorsal fin in front of the caudal spine; spine often duplicated; a fleshy flap around the front of the head formed by the joined "cephalic fins"; teeth large and flat, pavement-like, a row

⁷ We are unable to supply a key to differentiate the two forms of *Aetobatus* recorded here. A review of the illustrations of the Californian species demonstrates that Garman's key is useless, while the isolation of the species, over two thousand miles between the ranges of the two, demands that the two forms be maintained as separate species until proved otherwise.

of large teeth in the center with rows of smaller ones at the side. Dark brown, bronzed or greenish; lower surfaces white, darker toward the tips of the fins. (Illustration after Walford, 1935.)

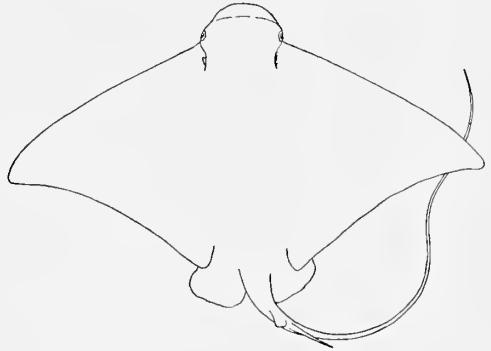
Size: Grows to about 4 feet wide and to a weight of 150 pounds.

Study Material: None.

References: *Rhinoptera vespertilio*, Girard, C. F., *Proc. Acad. Nat. Sci. Phila.*, 8, 1856: 137 (Tomales Bay, California; not *Myliobatis vespertillo* Bleeker).

Myliobatis californicus, Gill, T. N., *Ann. Lyc. Nat. Hist., New York*, 8, 1865: 137, after Girard, Osburn, R. C., & Nichols, J. T., *Bull. Amer. Mus. Nat. Hist.*, 35, 1916: 145 (Mexico: Port San Bartholome, several specimens; Santa Maria Bay, one specimen). Wales, J. H., *Copeia*, 1932: 163 (Mexico: Turtle Bay, 5 seined). Walford, L. A., *Dis. Fish and Game, California, Fish Bull.*, 28, 1931: 40, fig. 18 (diagnosis, notes, figure, grows to 4 feet). Walford, L. A., *ibid.*, 45, 1935: 61, fig. 56 (diagnosis, general notes, figure attains a weight of 150 pounds). Barnhart, P. S., *Marine Fishes of Southern California*, 1936: 14, fig. 39 (short description, range, figure).

Aetobatus peruvianus (Garman).⁸



Text-figure 34.

Range: Peru (Paita, Callao).

Field Characters: Similar to those of *A. californicus*. (Illustration after Garman, 1913, 600 mm.)

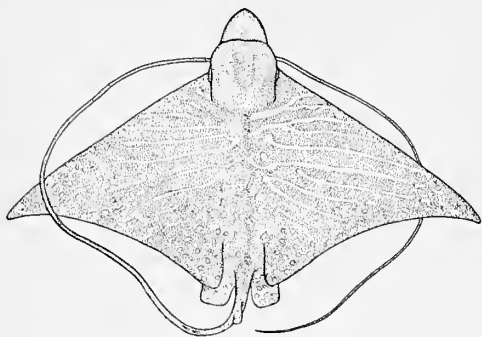
Size: The largest recorded specimen is 26 inches across the disk.

Study Material: None.

References: *Myliobatis peruvianus*, Garman, S., *The Plagiostomia*, 1913: 430, Plate 36, fig. 4-6, Plate 55, fig. 8, Plate 73, fig. 2 (original description: type locality, evidently Peru by the specific name; figure of entire fish, head from below, teeth, anterior skeleton; type in Mus. Comp. Zool. ?).

Myliobatis californicus, not of Gill. Evermann, B. W., & Radcliffe, L., *Bull. U. S. Nat. Mus.*, 95, 1917: 17 (Peru; Paita and Callao; short description of 580 mm. and 715 mm. fishes, color). Abbott, J. F., *Proc. Acad. Nat. Sci. Phila.*, 1899: 331 (local name, few measurements of a specimen from Callao, Peru. Range stated as "Cape Mendocino, San Diego, Callao").

⁸ More than 2000 miles separate the range of this form from that of *californicus*. It is evident that no idea can be obtained from the literature as to the relationships of these two forms. Such characters as were used by Garman (1913: 428) for the differentiation of the Pacific forms, fail to adequately distinguish them. This is especially evident when illustrations of *californicus* such as those given by Walford and Barnhart are studied, and compared with Garman's description and keys.

Pteromylaeus Garman, 1913.*Pteromylaeus asperrimus* (Gilbert).

Text-figure 35.

Range: Panama Bay.

Field Characters: A large ray with wide, pointed wings, projecting snout; sides of the head free from the pectoral fins; teeth in more than three rows in each jaw; tail whip-like with a spine near the base. Upper surfaces brownish; anterior part of the body and fins with narrow transverse bars of bluish-white which break up into a series of spots toward the outer margins of the fins, the posterior bars also breaking up into spots towards the mid-line of the body, posterior edge of wing with bluish white spots. (Illustration after Gilbert & Starks, 1904, width of disk 345 mm.)

Size: Grows to a width of 790 mm. across the wings.

Study Material: None.

References: *Myliobatis asperrimus*, Gilbert, C. H., in Jordan, D. S., & Evermann, B. W., Fishes North and Middle America, 3, 1898: 2754 (original description, dimensions; type locality, Panama; Type, No. 11,895, Stanford University). Gilbert, C. H., & Starks, E. C., Fishes of Panama Bay, 1904: 19, Plate 3, fig. 6 (description, measurements; figure, Panama. This is a copy of the original description with punctuation and arrangement somewhat altered). Garman, S., *Bull. Mus. Comp. Zool.*, 46, 1906: 229 (Panama).

Pteromylaeus asperrimus, Garman, S., *The Plagiostomia*, 1913: 438 (description, color; Panama). Meek, S. E., & Hildebrand, S. F., *Marine Fishes of Panama*, 1, 1923: 92 (Panama; description, color; no specimens).

Stoasodon Cantor, 1849.*Stoasodon narinari* (Euphrasen).

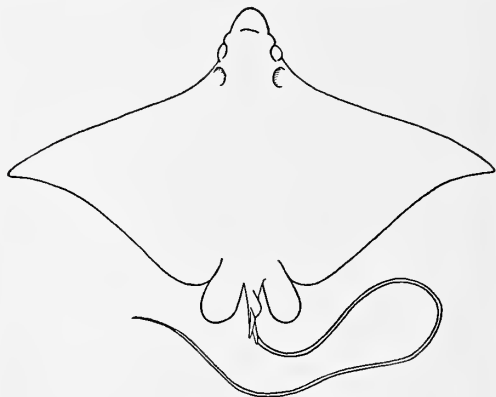
Range: Tropical Atlantic and Pacific. In the eastern tropical Pacific known from Mexico (Gulf of California, "west coast," Mazatlan), Costa Rica (Golfito, Gulf of Dulce), Panama (Panama Bay), and the Galápagos Islands (Hood and Seymour).

Field Characters: A large flattened ray with pointed wings; tail long, whip-like, without a caudal fin; a spine (occasionally two) at the base of the tail. Teeth in a single row, forming a long flattened plate, placed lengthwise in the lower jaw, crosswise in the upper. Brown to gray to

black above, the entire body and head covered with many round, sometimes elliptical, white or yellowish spots; ventral side white, bordered sometimes with darker toward the tips. (Illustration after Jordan & Evermann, 1900.)

Color: (730 mm.-wide specimen from South Seymour Island, Galápagos Islands). Black above, covered with numerous grayish white spots narrowly bordered with pale grayish-blue, which average 8 mm. in diameter and are about 12 to 15 mm. apart. Cephalic fins black; forehead and suborbital area mottled gray and white. Under parts white except for a narrow grayish-black irregular border to the cephalic lobe, and the outer half of each pectoral fin which is irregularly mottled and marbled with grayish-black. This pattern extends faintly and narrowly along the anterior edge almost to the head and more broadly towards the rear edge of the fin towards the vent. Each pectoral is broadly edged with black along the distal half of the anterior and all of the posterior edge. Proximal part of the tail as far as the spines with oblique gray lines alternating with white. Dusky mottling between the gill slits. Iris brownish-black, shading to grayish-white around the pupil.

Size: Grows to 12 feet long, 7.5 feet across the disk, and an estimated weight of 450 pounds. An 11-pound ray measured 730 mm. across the disk.



Text-figure 36.

Study Material: 4 specimens. Galápagos Islands: Seymour Island, 1 (5231), 730 mm. across the disk, April 5, 1925, harpooned. Galápagos Islands: Hood Island, 3 (5,503, 5,504, 5,505), 490, 495, 520 mm. across the disk, April 26, 1925.

One ray about 12 to 15 inches across the disk was seen close to shore in shallows at Golfito, Gulf of Dulce, Costa Rica, March 7, 1938.

References: *Raia narinari*, Euphrasen, B. A., *Vedensk. Akad. Nya. Handl.*, 11, 1790: 217 (description, after Marcgrave).

Aetobatis narinari, Günther, A., *Cat. Fishes Brit. Mus.*, 8, 1870: 492 (synonymy in part; short description; Bay of Panama). Garman, S., *Bull. Mus. Comp. Zool.*, 46, 1906: 230 (Panama). Günther, A., *Trans. Zool. Soc. London*, 7, 1868: 491 (Panama Bay; brief comparison with Atlantic example).

Aetobatus narinari, Jordan, D. S., Fishes of Sinaloa 1895: 391 (Mexico: Mazatlan; comparison with description of *A. laticeps*, which is questioned as having come from the west coast of America; copy of original description of *laticeps*; mentions that species has been taken several times in the Gulf of California). Gilbert, C. H., & Starks, E. C., Fishes of Panama Bay, 1904: 18 (description; comments on Jordan's 1895 paper; size of spots variable, and length of tail unreliable). Garman, S., The Plagiostomia, 1913: 441, Plate 49, fig. 1-3; Plate 54, fig. 4; Plate 55, fig. 9; Plate 57, fig. 4; Plate 73, fig. 4 (synonymy, description, color, figures of teeth, pelvis, vertebrae, heart and skeleton). Breder, C. M., Jr., *Bull. Bingham Oceanogr. Coll.*, 2, (1), 1928: 13 (specimen from unknown locality on west coast of Central America and Mexico).

Stoasodon narinari, Jordan, D. S., & Gilbert, C. H., *Bull. U. S. Nat. Mus.*, 16, 1882: 879 ("... The species is abundant on the west coast of Mexico, from which region the typical specimen was most likely obtained"). Clark, H. W., *Proc. Cal. Acad. Sci.*, (4) 21 (29), 1936: 395 (Galápagos Islands; sight record only).

Stoasodon laticeps, Gilbert, C. H., *Bull. U. S. Fish Comm.*, 2, 1882 (1883): 105 (Mazatlan, Mexico).

Myliobatis narinari, Lay, G. T., & Bennet, E. T., Zoology of Captain Beechey's Voyage, London, 1839: 56 (Panama).

Aetobatus laticeps, Jordan, D. S., & Evermann, B. W., Fishes North and Middle America, 3, 1898: 2753 (synonymizes *laticeps* with *narinari*; description of specimens from Mazatlan, Mexico).

Pteromylaeus sp., Walford, L. A., Marine Game Fishes of the Pacific Coast, 1937: Plate 26, fig. c (figure).

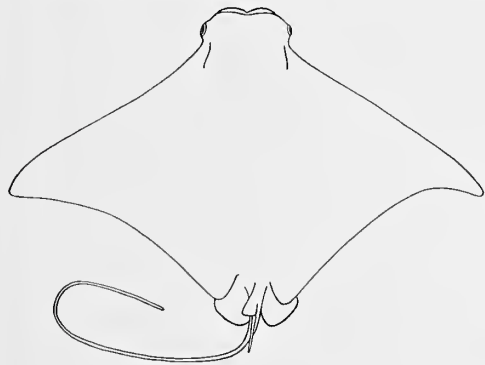
Discussion: All specimens seen by us were small and taken in March or April. However, the umbilical cord in these specimens has completely disappeared and there is no indication that these fish might recently have been born.

The specimen figured by Walford (1937) under the name of "*Pteromylaeus* sp." is considered a synonym of this species. Walford informs us that the specimen was not preserved.

Family RHINOPTERIDAE.

Rhinoptera (Kuhl) Cuvier, 1829.

Rhinoptera steindachneri Evermann & Jenkins.



Text-figure 37.

Range: Mexico (Gulf of California from Rio Colorado, and Guaymas, and an unknown locality along the coast of Mexico), Galápagos Islands (Chatham Island).

Field Characters: Medium sized rays with pointed wings and whip-like tail with serrated spine at the base; snout bilobed; upper surfaces dark gray, brown or black, lower surfaces creamy white, under the tips of the wings blackish.

(Illustration after Kumada & Hiyama, 1937, 646 mm. across disk.)

Size: Grows to a width of 710 mm. across the disk.

Study Material: None.

References: *Rhinoptera steindachneri*, Evermann, B. W., & Jenkins, O. P., *Proc. U. S. Nat. Mus.*, 14, 1891 (1892): 130, Plate 1, fig. 1 (description, measurement of two specimens, color, figure, figure of teeth; type locality, Guaymas, Mexico; type No. 43,235, U. S. National Museum). Jordan, D. S., & Evermann, B. W., Fishes North and Middle America, 1, 1896: 91 (copied description, common name). Jordan, D. S., & Evermann, B. W., Fishes North and Middle America, 4, 1900: figs. 38 and 38a (copied figure of animal and teeth). Garman, S., The Plagiostomia, 1913: 446 (description). Breder, C. M., Jr., *Bull. Bingham Oceanogr. Coll.*, 2 (1), 1928: 13 (2 specimens from between San Felipe and Shoal Point, Rio Colorado, in trawl at 10-14 fathoms). Kumada, T., & Hiyama, Y., Marine Fishes of the Pacific Coast of Mexico, 1937: 24, plate 58 (brief notice; figure of upper and figure of part of lower surface). Fowler, H. W., *Acad. Nat. Sci. Phila., Monograph* 2, 1938: 19 (description, color, specimen from Chatham Island, Galápagos Islands).

Family MOBULIDAE.

Key to tropical eastern Pacific genera.

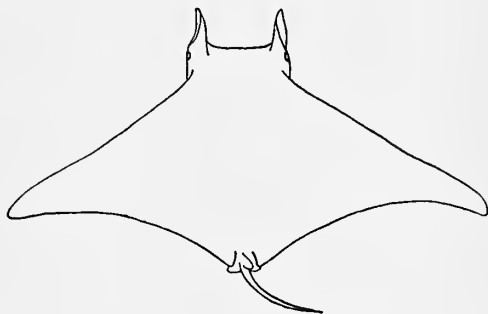
1a. Mouth inferior; teeth in both jaws. . . *Mobula*.

1b. Mouth terminal; teeth in lower jaw only. . . *Manta*.

Mobula Rafinesque, 1810.

Mobula lucasana Beebe & Tee-Van.

(Plate IV, Fig. 1).



Text-figure 38.

Range: San Lucas Bay, Lower California, with uncertain records from the coast of Costa Rica, and the Gulf of California.

Field Characters: Rays with pointed wing-like pectoral fins, and with two fleshy appendages on the head; mouth on under surface of head; teeth in both jaws; black above, whitish beneath. (Illustration after Beebe & Tee-Van, 1938, 1,035 mm. across disk.)

Description: The following is a copy of the original description:

"Skin smooth, no trace of rugosities or spines anywhere. Width across disk, 1,035 mm.; length from anterior margin of disk to posterior margin of the pelvic fin 584 mm. (anterior margin of the disk considered as being at the mid-line of the body, thus not including the cephalic

projections); cephalic fins extending forward 80 mm., beyond the anterior margin of the disk, the distance between their tips approximately 150 mm., distance from upper margin of the cephalic fin to lower margin of the fin when the fin is unfurled, 58 mm. Eye lateral, 17 mm. in diameter, its anterior margin 88 mm. from the tip of the cephalic fin. Spiracle oblique, 31 mm. posterior to the eye. Mouth inferior, 128 mm. wide, very slightly concave when viewed from below, the margin of the upper lip 40 mm. from the anterior margin of the disk.

"Teeth in each jaw in a narrow band, each band extending 70 percent of the width of the mouth. Upper jaw with 80 transverse rows of teeth and 5 rows from back to front. Lower jaw with 97 teeth in a transverse series and with 4 or 5 rows from back to front. Teeth small, flattened, their surfaces slightly roughened, the posterior border with 2 to 5 dull, irregular points. A typical tooth in the center of the lower jaw measures 1.2 mm. in width and .5 to .6 mm. in depth.

"Mouth to transverse line of first gill-openings 70 mm.; transverse distance between first gill-openings 133 mm.; transverse distance between last gill-openings 60 mm.; length of gill-slits of first four pairs of gill-openings 52 mm.; length of last gill-slit 37 mm.

"Pelvic fins rather elongate, their tips extending 31 mm. beyond the posterior tip of the pectoral, the inner margin extending backward farther than the outer, the fin nearly uniform in width, averaging 38 mm.

"Dorsal fin with its posterior one-fourth situated above the free portion of the tail, the base of the fin 57 mm., the height 46 mm.

"Tail immediately beyond the dorsal fin flattened, the skin of its upper surface reticulated, the reticulations being in the form of minute low, raised ridges of skin, the upper margins of which are roughened and occasionally slightly ciliate. Although the area mentioned above has this peculiar specialized skin there is no trace of a spine or of the beginnings of a spine. Tail beyond the expanded portion becoming attenuated near the tips of the pelvic fins, its diameter 50 mm. posterior to the tips of the pelvic fins being 3.5 to 4 mm.

"Color: In life upper surfaces, including the area about the eye and the upper part of the cephalic fins, blackish-gray; lower surfaces whitish becoming bluish-gray toward the tips of the wings, this color darkest on the anterior portion of the fins. Leading edge of undersurfaces of pectoral fin dusky, the posterior edges similarly colored but the band of color narrower. An oval, dusky spot near the posterior margin of the lower side of the pectoral fin, slightly nearer the pelvic fins than the tip of the pectoral. Tip of the cephalic fin black.

"The preserved type has the underside of the body, anterior to the mouth, and a narrow band along the lower jaw as well as the entire inner surface of the cephalic fin, brownish-black."

General Habits: These fish were common at San Lucas Bay and about Cape San Lucas. A number of individuals were seen somersaulting in the air and striking the water in descent with a sound audible for considerable distances. Others, presumably this species, were seen in Santa Inez Bay, Gulf of California, and off the west coast of Costa Rica.

Study Material: 1 specimen. Mexico: Cape San Lucas, 1 (24,793) the type of the species, 1,035 mm. across the disk, Mar. 30, 1936.

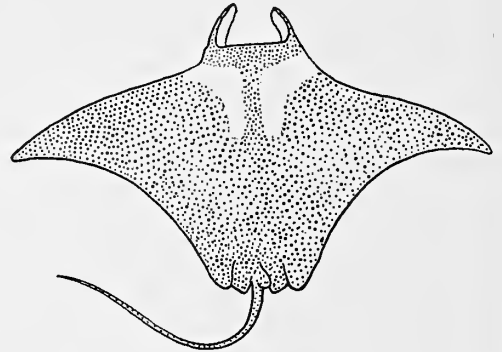
References: *Mobula* sp. Walford, L. A., Marine Game Fishes of the Pacific Coast, 1937: Plate 26, fig. d. (figure of upper surfaces).

Mobula lucasana, Beebe, W., & Tee-Van, J., *Zoologica*, 23 (15), 1938: 229-301, Plate 1, figs. 1, 2, Plate 2, figs. 3, 4, Plate 3, fig. 5 (original description, color, comparison with other eastern Pacific forms, figures of entire animal, lower surface of head, cephalic fins, posterior portion of body with dorsal fin, teeth. Type No. 24,793, Department of Tropical Research, New York Zoological Society; type in the collection of the American Museum of Natural History).

Manta hamiltoni (Newman).

Manta, Sea-Devil, Manta-ray.

(Plate IV, Fig. 2).



Text-figure 39.

Range: Warm waters of the eastern Pacific. Recorded from the Marquesas Islands, and along the American coast from the following localities; California: Redondo, San Pedro, San Diego; Mexico: Gulf of California, Guaymas, Mazatlan, Gorda Banks, Banderas Bay, Guatulco; Panama: Bahia Honda, Panama Bay, Pearl Islands; Peru: Zoritos, Tumbes; Clarion Island; Cocos Island; Galápagos Islands: Tower, Albemarle, Narborough.

Field Characters: Giant rays with pointed wings and large horn-like cephalic flaps; a long whip-like tail; mouth at front of body, not below; teeth present in the lower jaw only. Color, black above with large white symmetrical patch on each shoulder, the white at times almost invisible; white and black and gray below, the outer edges of the wings dark. (Illustration from specimen 6652, 18 feet across disk.)

Dimensions: Comparative measurements made in the field of mother and embryo are as follows (specimen 6652, Narborough Island, Galápagos, June 11, 1928):

	Adult	Young	Percent- age of Adult
Total spread	4572 mm.	1140 mm.	25
Lower jaw to anus	1800	440	24.5
Lower jaw to tip of broken tail	2800	—	—
Breadth along posterior wing	3050	540	17.7
Length anterior gill slit	625	115	18.3
Length posterior gill slit	390	80	20.5
Antero-posterior gill area	450	120	26.6
Distance between right and left posterior gills	310	70	22.5
Distance between right and left anterior gills	605	125	20.6
Cephalic Appendages:			
Length, posterior edge	720	145	20
Greatest width	274	60	21.7
Width base	350	63	18
Width mouth	870	170	19.5
Base cephalic appendage to 1st gill slit	380	70	18.5
Length ventral fin, outer border	520	95	18.2
Width head, eye to eye	1400	305	21.8
Eye diameter, eye ball	84	12	14.2
Iris	38	5	13.2
Base of dorsal fin	200	70	35
Height of dorsal fin	230	55	23.9
Front of head to dorsal fin	1830	450	24.5
Total length of tail	880	540	—
	(broken)		
Weight	2310 lbs.	28	12.1

Measurements as to the teeth and the extent of the teeth band in the embryo are as follows: The width of the mouth in the preserved specimen is 157 mm., and the tooth band extends across 75% of this width or 116 mm. At the rear of the tooth band there were 96 rows of teeth in a transverse series.

Color: The eighteen-foot-wide female taken at the Galápagos Islands was colored as follows: Above black (but see under *Discussion*), below dark bluish with the exception of a large white triangle on the anterior proximal portion of the wing; in other words, there is a wide dark outer border to the wing. Posterior edge of all gill slits white. Cephalic fin jet black above with a broad center of pale turquoise blue clouding.

Embryo, 28 inches across the disk: Above jet black with faint grayish white shading back and in from the nostril nearly to mid-line of back and then back in a foot-shaped mark with the sole lying not far from the mid-line and the toes just above the beginning of the body cavity (field description of white shoulder patch). Below pinkish-white with symmetrical bluish-black patches as follows: entire eye protuberance, a spot below and one-third toward center of mouth, a large irregular rounded patch back from the outer half of the posterior gill-slits, and a large cloud-like patch V-ing up from the anus and out toward the posterior gill slits. Distal half of the wings darker than the anterior proximal portion.

There appears to be considerable variation of the color of the under surface, but this general pattern was repeated on a cut-up specimen seen

in a fisherman's boat at Panama, that had the underside of the single remaining pectoral fin half black. We also noted that markings on these animals fade considerably with drying. The anterior edge of the tips of the wings is white.

Size and Weight: Grows to 18 feet 6 inches across the disk. Our 18-foot specimen weighed 2,310 pounds and the 1,140 mm.-wide (45 inches) embryo weighed 28 pounds.

Breeding: On the date of capture, June 11, 1925, the embryo had its tail protruding from the female, and the yolk sac was almost completely absorbed; hence it would probably have been born in a day or two. The yolk sac remained as a knotted string, six inches long.

Pellegrin (1901) noted that the species mated in May in the Gulf of California.

General Habits: Remoras are particularly abundant commensals of the mantas. Typical of our notes in regard to this matter are those relating to mantas and remoras seen at the Pearl Islands and recorded as follows:

" . . . From each side of the front part of the wings two large *Echeneis* clung. Each was at least two and a half feet long, very thick and stout, and white beneath, which was of course the visible part above as they clung upside down. They never changed places and very often their widely gaping, scarlet gills were high out of water. Six or eight smaller suckers, some not more than three or four inches were slithering over the black and white back of the manta. The same day we saw several more mantas like this first."

References: A. References definitely referring to mantas with white shoulder patches.

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Giant Ray, Gray, Z., "Tales of Fishing Virgin Seas," 1925: 60-61 (Indefatigable Island, Galápagos Islands, figure of white marked specimen 15 feet across), 71 (Galápagos Islands, leaping out of water), 73 (Galápagos Islands, leaping out of water to remove remoras), 81, 82 (swimming); plate xvii (photograph of white marked specimen).

Manta birostris, Walford, L. A., *Calif. Fish and Game*, 17 (4) 1931: 404, fig. 112 (San Pedro, California; photograph of female specimen lying on dock, fourteen feet across).

Manta pinchoti, Whitley, G. P., *Australian Zoologist*, 8 (3) 1936: 182, based on *Manta birostris* of Fowler, H. W. (*Proc. U. S. Nat. Mus.*, 80 (6), 1936: 2), (Not *Manta birostris* Walbaum), part referring to the Marquesas "Sea Bat" described and figured by Pinchot, "To the South Seas," 1930: 405 et seq., 415, 411, 412, 417, 419.

B. References indefinite as to color.

Ceratoptera, Streets, T. H., *Bull. U. S. Nat. Mus.*, 7, 1877: 54 (Gulf of California).

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Manta hamiltoni, Beebe, W., "The *Arcturus* Adventure," New York and London, 1926: 123, 134, 135, 206, 304, 415, 434, figs. 30, 35 (Galápagos Islands, capture, figure; this record refers to a white-shouldered manta, although there is no mention of such color).

Cephaloptera birostris, Oustalet, E., *La Nature*, 25, 1899: 273-274 (Mexico: Guaymas; figure, general account, remoras).

Ceratoptera birostris, Pellegrin, J., *Bull. Mus. Nat. Hist. Paris*, 7, 1901: 161, 167 (Gulf of California; size and measurements, copulation in May; "La femelle est ovovipare").

Manta birostris, Jordan, D. S., & Gilbert, C. H., *Bull. U. S. Fish Comm.*, 2, 1882 (1883): 105 (Mexico: Mazatlan). Jordan, D. S., *Fishes of Sinaloa*, 1895: 394 (Mexico: Mazatlan; "Said to be frequently seen in the open sea

about Mazatlan; not seen by us"). Snodgrass, R. E., & Heller, E., *Proc. Wash. Acad. Sci.*, 6, 1905: 346 ("We frequently saw, amongst the islands of the Galapagos archipelago, enormous rays probably belonging to this species, but no specimens were obtained"). Vaillant, L. L., & Diguët, L., *Bull. Mus. Paris*, 4, 1898: 127-129 (Gulf of California; notes on habits, capture). Baer, G. A., *Bull. Mus. Hist. Nat. Paris*, 5, 1899: 111-112 (Peru; Zorrilo: notes). Vaillant, L. L., *Bull. Mus. Hist. Nat. Paris*, 5, 1899: 112, 113 (notes). Smith, H. M., *The Fishes of North Carolina, North. Car. Geol. and Econ. Survey*, 2, 1907: 48 (Gulf of California; use of cephalic appendages). Fowler, H. W., *Proc. U. S. Nat. Mus.*, 80, 1932: 12 (remoras taken from manta at Tower Island, Galápagos), 13 (same). Herre, A. W., *Feld Mus. Nat. Hist., Zool. Ser.*, 21, 1936: 25 (Cocos Island, Galápagos Islands; habits; leaping out of water; swimming near surface with upturned wings). Fowler, H. W., *Acad. Nat. Sci. Phila., Monograph* 2, 1938: 249 (Galápagos Islands localities: Albemarle, Narborough, Tower; Cocos Island). Schmitt, W. L., *Annotated List of Fishes, Presidential Cruise, 1938*: 5 (Cocos Island; 1645 pounds, 15 feet wide and 9 feet long, exclusive of a 4 foot tail). Schmitt, W. L., *Explorations and Field Work of the Smithsonian Institution in 1938*: 12 (Same record as reference immediately above). Manter, H. W., *Allan Hancock Pacific Expeditions*, 2 (14), 1940: 440 (Panama: Bahía Honda; trematodes).

"Ray," Pinchot, G., "To the South Seas," 1930: 148-158 (Tower Island, Galápagos; photographs, capture, color; data sent to U. S. National Museum).

Study Materials: 2 specimens, Narborough Island, Galápagos Islands, 2 (6652, 6653) adult female and male embryo, 5,486 mm. (18 feet) across disk and 1,140 mm. respectively, June 11, 1925 (*Arcturus* Oceanographic Expedition). Besides these specimens this fish has been seen by us at the following localities: Gulf of California between Guaymas and Santa Inez Island (one seen), up to 16 feet in width; Clarion Island, (four seen); Mexico: Banderas Bay (one seen); Gorda Banks (one seen) and Guatulco (several seen up to 16 feet in width); Panama: Pearl Islands, one seen at close range and photographed, several others seen.

Discussion: While endeavouring to thrash out the relationships of the Pacific coast manta and the Atlantic *Manta birostris*, the following notes were made. Many of the questions that arise as to these animals cannot fully be answered without further studies and especially those made in the field with fresh material, but we may mention that the evidence indicates separation of Pacific *hamiltoni* with immaculate white shoulder patches from Atlantic *birostris* with black spots in white shoulder patches.

Newman, in 1849, described *Brachioptilon hamiltoni* from the Gulf of California, this being the first account of a manta from the eastern Pacific. Newman's name was based upon a letter from Commander Cospatrik Baillie Hamilton of H. M. S. *Frolic*, in which Commander Hamilton described the capture in the Gulf of California of what was obviously a manta.⁹ The description given in this letter and in Newman's notes on an unpublished drawing of the fish mentions only the size of the animal and the fact that it possessed "a sort of arm projecting from the shoulder." The size of the

fish, 19 feet in width, is the only factor that indicates that the fish was of the genus *Manta* and not *Mobula*. There are no records of an eastern Pacific *Mobula* growing as large as 19 feet across the disk.

Most authors since Newman have placed *hamiltoni* in the synonymy of *birostris*, thus considering the mantas of the Atlantic and Pacific as one and the same species. As mantas are difficult to compare because of size and the problems of preserving them, and as relatively few have been studied alive by ichthyologists, such a conclusion was more or less inevitable.

In 1924 Beebe published a note about a manta seen at Tower Island, Galápagos, that had large conspicuous white patches on the shoulders and in 1932 he noted others at the Pearl Islands, Panama Bay. Zane Grey in 1925 recorded similarly marked specimens at the Galápagos Islands, and Walford in 1931 gave an illustration under the name of *Manta birostris*, of a white-shouldered manta taken at San Pedro, California. During the Eastern Pacific *Zaca* Expedition several white-shouldered mantas up to 16 feet in width were observed at Port Guatulco, Mexico, on Dec. 3, 1937. Recently white-shouldered mantas were the subject of motion pictures taken on the coast of Peru by the Michael Lerner Expedition. These six accounts represent all of the definite records in the eastern Pacific of white-shouldered mantas.

Pinchot in 1930 published excellent illustrations of a white-shouldered manta that he had taken at the Marquesas and in 1936 this fish was named *Manta pinchoti* by Whitley. A comparison of the various descriptions and illustrations mentioned above leaves no doubt in our mind that the eastern Pacific and the Marquesas mantas belong to the same species.

In attempting to clarify the status of the white-shouldered mantas, certain questions arise:

1. Is the white-shouldered color pattern confined to one sex?

This question can be answered in the negative, as our 18-foot-wide, 2,310-pound female with white shoulder patches, carried a male embryo weighing 28 pounds that also had the same markings.

2. Do all of the eastern Pacific mantas have white shoulders?

An unqualified answer to this question must await further observations, but from the available evidence the answer would seem to be "Yes." This conclusion is based primarily upon the supposition that the white shoulder-patches may be masked (as is suggested later on) so that they are not visible, and, secondly, that even when they have been observed little attention was paid to them and to their significance. We also believe that the same conditions hold true for the Atlantic manta, which as is shown later on in these pages, also possesses white shoulder-patches.

In support of this conclusion our own experience with mantas, and especially with a manta

⁹ In Commander Hamilton's letter there is the following account of the lifting aboard ship of this fish: ". . . I could not ascertain the weight; but some idea may be formed by the fact that sixty men were unable to lift him on board with the yard tackles: the heaviest purchases in the ship, with one hundred and fifty men were required for the purpose. . . ." Evidently the lifting of a ton to a ton and a half was a formidable enterprise on a man-of-war in 1846.

captured by us in 1925 on the *Arcturus* Oceanographic Expedition, is especially pertinent. Some of our field notes relating to these fishes, which were exceedingly common off the west coast of Albemarle Island and the north Coast of Narborough Island in the Galápagos group, are as follows:

"Station 84, 1 mile north of Narborough Island, June 9, 1925. DEVIL FISH. Common both near shore and three miles out, keeping much on the surface. The back comes up and might be a seal except for its great width. It then submerges and the tips of the wings appear, sticking straight up, black on the inner side and white on the outer side. When by chance only one wing protrudes it resembles a shark's fin, and when further out it looks like the dorsal fin of a blackfish.

"They are not very wary and for an hour we played with one in two boats, bumping into it continually and being splashed by the thrashing wing-tips as it turned. There were two, about ten feet spread, one of which had lost a piece of the tip of the left wing. They refused to go down and were swimming along when we left them.

"The boys had no trouble in harpooning a large one but it swam off with two harpoons and two kegs. The second one put up only a comparatively feeble fight and they were able to head it to the steamer. It was 18 feet tip to tip and weighed somewhere about 2300 pounds. A young one was about to be born, weighing 28 pounds."

Motion pictures were made of the capture of this female manta and of its being hoisted aboard the *Arcturus*, and many notes were recorded about this fish and its embryo, but *nowhere* is there a mention of the adult manta possessing white shoulder-patches, although the field notes contain data to the effect that the embryo after extraction from its mother did have indications of white shoulder-patches.

To check on whether the adult did or did not have white shoulder marks, the motion picture negative of the capture of the fish was looked over. Practically all of the film shows the underside of the fish, but, fortunately, a small section shows part of the upper surfaces and is reproduced here as Plate 4, Fig. 2. This photograph definitely shows, although vaguely, the presence of white shoulder patterns and we thus have definite proof that both male and female Pacific mantas possess these white patches.

At least three ichthyologists saw this manta at the time of capture and the fact that no especial comment was made as to the white on the upper surfaces seems to be of significance; evidently the white marks are not always sufficiently prominent as to cause comment, and they may not always be visible.

In this connection it may be remarked that the preserved 28-pound embryo now shows no trace of the white shoulders that were evident when it was removed from its mother.

There is a possibility that the solution to the

masking of the white patches on the dorsal surface of the mantas, may be laid to pigment carried in the outer skin which becomes free and at times overlays the white patches. Coles,¹⁰ writing of the Atlantic manta, has the following note: ". . . The color of the back of *Manta* is dead black, although specimens are frequently observed with dirty white patches showing on the dorsal surface. This change of color is due to the scraping off of the superficial coloring layer when the fish has been swimming at the surface for some time; the black color is restored when the *Manta* has remained beneath the surface for some time. While washing off the surface of a *Manta*, both the cloth and the water used became colored black by pigment, and the whole dorsal surface became lighter in color. I have also placed a handkerchief upon the skin of a dying *Manta* and observed that it was heavily coated with black coloring matter discharged from the skin."

Pinchot¹¹ gives similar evidence as he states that the dorsal color of a Tower Island, Galápagos manta was "very dark gray or black carried in a thin slimy outer skin that came off easily in the hands."

3. Is the manta of the tropical eastern Pacific, *Manta hamiltoni*, distinct from the Atlantic manta, *Manta birostris*?

We have not been able to gather sufficient evidence uncomplicated by differences in age, etc., to answer the question as far as morphology is concerned. From the standpoint of color, however, the following notes were made.

The literature of the Atlantic manta, *M. birostris*, with the exception of two references that are discussed below, consistently list the color of the upper surfaces as being black, with no mention of a symmetrical white pattern on the shoulders. There are occasional statements of white patches, unsymmetrical in form and placing, that apparently are caused by abrasions.

The exceptions to the almost unanimous recording of a uniformly colored dorsal surface in *birostris*, are as follows. In C. F. Holder's volume "Big Game at Sea" (Outing Publishing Co., New York, 1904) on the plate facing page 24, there are four photographs of a large manta, and in two of these, prominent, white symmetrical shoulder-patches are present. The plate contains no data as to where the manta was taken, but on page 35 there is the following statement referring to St. Petersburg, Florida, which would be presumed to relate to the photographs: ". . . Dozens of kodaks and cameras were in evidence, and the devil-fish was the most photographed curiosity the city has seen for many a day."

As this record was not as definitely labelled as it might have been, and as most of Holder's volume referred to Pacific fishes, the possibility that a photograph of a Pacific manta with white

¹⁰ Coles, R. J., *Bull. Amer. Mus. Nat. Hist.*, 35, 1916: 653, 654.

¹¹ Pinchot, G., "To the South Seas," 155.

shoulder-patches had been substituted as an illustration for a Florida specimen, was considered. As the mantas of the Atlantic and Pacific had been recorded as the same species, such a substitution would not have been too far-fetched.

Many of the chapters in Holder's volume were first published in magazines, and a search was therefore started through old files in an endeavour to substantiate or disprove the verity of the photographs. Surprisingly enough, the fact that the photographs were taken in Florida was validated by completely independent evidence. In "Outing" Magazine, volume 39, 1902, on page 560, in an article written by R. B. Seager entitled "Tarpon and Sharks on the east coast of Florida," there is an excellent photograph of a manta taken at Punta Rassa, on the west coast of Florida, which shows very prominent, symmetrical, white shoulder-patches. These patches agree perfectly with those shown on the Holder specimen in having a series of small black spots down the center of the white; there is no indication of these internal dark spots in any of the illustrations of Pacific mantas.

In our own files, we have a drawing of a manta that was seen on June 11, 1930, off Bermuda, under the bow of the vessel while we were making one of the bathysphere dives. This manta, estimated to be about twelve feet across the disk, had white shoulder-patches and a white chevron-like mark on the posterior part of the disk near the tail. The shoulder-patches in the drawing are elongate, somewhat crescentic spots, with no sign of black inner spots, situated in the correct position but wider apart and somewhat differently shaped than those of the Florida specimens mentioned above. The accuracy of the shape and the presence or absence of black spots, can of course be questioned, as this plate was based upon a sight record of short duration.

We thus have proof that both Atlantic and Pacific mantas do have white shoulder-patches.

Also, based on the same evidence, the Atlantic and the Pacific mantas can be differentiated by the presence of dark spots within the white patches in the Atlantic fish and by the absence of the dark spots in the Pacific manta.

4. Is there a white-shouldered and a non-white-shouldered species in each ocean?

We believe that the answer to this question is "No," and suggest that future investigators of live material check on the possibility that the white patches are masked by black free pigment.

Summarizing the above notes, the following observations can be made:

a. *Manta pinchoti* Whitley may be synonymized under *Manta hamiltoni*, as the Marquesas form shows no differences from the coastal eastern Pacific form, for which the name *hamiltoni* is available.

b. The white-shouldered pattern is found in both sexes of Pacific mantas.

c. Both Atlantic and Pacific mantas possess white shoulder-patches, the intensity of coloration being variable, and the white patches are possibly masked by the presence of loosely attached black pigment.

d. The Atlantic mantas with white shoulder-patches have black spots in the patches, while the tropical eastern Pacific form has immaculate shoulder markings.

e. No evidence is adduced as to the possibility of there being a white-shouldered and a non-white-shouldered species in the Atlantic and in the tropical eastern Pacific. It is believed that only one form is present in each of these regions.

Subclass HOLOCEPHALI.

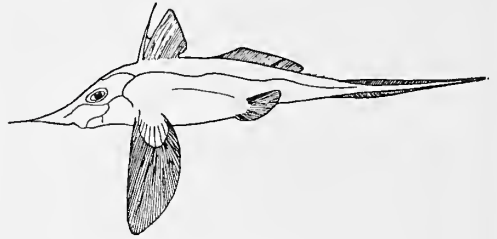
Key to families of the tropical eastern Pacific.

- 1a. Snout produced into a long simple beak.
Rhinochimaeridae, p. 278.
- 1b. Snout produced into a leaf-shaped flexible appendage.....*Callorhynchidae*, p. 279.

Family RHINOCHIMAERIDAE.

Harriotta Goode & Bean, 1895.

Harriotta curtiss-jamesi Townsend & Nichols.



Text-figure 40.

Range: Known only from a single locality off the west coast of Lower California (90 miles N. W. of Cape San Lazaro) in 645 fathoms.

Field Characters: Small fishes with long, simple, beak-like snout and an elongate tapering filamentous tail; first dorsal fin rather high and preceded by a spine; pectoral fins large and wing-like; color black. (Illustration after Townsend & Nichols, 1925, 152 mm.)

Size: The only known specimen is six inches long.

Abundance: Rare, one specimen known.

References: *Harriotta curtiss-jamesi*, Townsend, C. H. & Nichols, J. T., *Bull. Amer. Mus. Nat. Hist.*, 52, 1925: 6, fig. 2 (original description, color, figure; type No. 8342, Amer. Mus. Nat. Hist., type-locality, Albatross station 5685, 25° 42' 45" N., 113° 38' 30" W., 90 miles N. W. of Cape San Lazaro, Lower California, 60 miles off the nearest land, in 645 fathoms).

Family CALLORHYNCHIDAE.

Callorhynchus Lacepede, 1798.*Callorhynchus callorhynchus* (Linnaeus).

Range: Southern Brazil, Argentina, Chile and Peru (Peru: La Ventanilla, Callao).

Field Characters: Fishes with a flexible proboscis ending in a leaf-like terminal portion; first dorsal fin rather high and preceded by a spine; color silvery with age, varying dark or pale; young with black spots.

Size: Grows to over 800 mm.

Study Material: None.

References: *Chimaera callorhynchus*, Linnaeus, Syst. Nat., ed. 10, vol. 1, 1758: 236 (type locality "In Mari Aethiopici").

Callorhynchus callorhynchus, Starks, Proc. U. S. Nat. Mus., 30, 1906: 764 (description, color, Callao, Peru) Evermann and Radcliffe, U. S. Nat. Mus., Bull. 95, 1917: 18 (synonymy, dimensions, description, color; La Ventanilla, Peru). Norman, Discovery Reports, 16, 1937: 35-36 (description; synonymizes *smythii* under *callorhynchus*).

Callorhynchus smythii, Lay and Bennett, Zoology Beechey's Voyage, Fishes, 1839: 75, Plate 22, fig. 3 (original description based upon a drawing by Smyth; La Concepcion, Chile).

Callorhynchus smythii, Garman, Mem. Mus. Comp. Zool., 40, 1911: 98.

Callorhynchus tritoris, Garman, Bull. Mus. Comp. Zool., 41, 1904: 257, 271, Plate 6, fig. 9 (type-locality: Mexillones, Peru?).

Callorhynchus smythii, Fowler, U. S. Nat. Mus. Bull., 100, Vol. 13, 1941: 508-509 (description, color, synonymy).

Discussion: Three forms of *Callorhynchus* have been reported from Peru: *callorhynchus*, *smythii*, and *tritoris*. The recent taxonomic history of the west coast Pacific form is as follows: Fowler (Bull. 100, U. S. Nat. Mus., Vol. 13, 1940: 509-510) synonymized *tritoris* under *smythii*; Norman, Discovery Reports, 16, 1937: 35-36) synonymized *smythii* under *callorhynchus*; and Fowler, in "Los Peces de Peru" (Bol. Mus. Hist. Nat. "Javier Prado," Ano 5, No. 17, 1941) lists only *Callorhynchus callorhynchus*.

Mexillones, Peru, the type locality of *tritoris*, as stated by Garman, may refer to Mexillones or Mejillones, Chile, in which case the supposed Peruvian record of the nominal *tritoris* does not come under the geographical limits of this publication. The U. S. Navy Hydrographic Office publications (Pilots and charts) give no mention of Mexillones or Mejillones in Peru.

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FOWLER, H. W.

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TERRON, C. C.

Lista de los Peces de la Costas de la Baja California. Anales del Inst. Biol., Univ. Nac. Auton. Mexico, III, 1932: 75-80.

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A Check List of the Fishes of southern California and Lower California. Journ. Pan-Pac. Res. Inst., 4 (4), 1929: 2-11.

EXPLANATION OF THE PLATES.

PLATE I.

- Fig. 1. *Narcine vermiculatus*. Specimen from off La Libertad, El Salvador, 13 fathoms, 58 mm.
 Fig. 2. *Discopyge ommata*. Specimen from Santa Inez Bay, Lower California, 168 mm.

PLATE II.

- Fig. 1. *Dasyatis pacificus*. Upper surface of holotype, length 1,524 mm.
 Fig. 2. *Dasyatis pacificus*. Lower surface of holotype, length 1,524 mm.
 Fig. 3. *Dasyatis pacificus*. Dorsal tubercles, $\times 10$.
 Fig. 4. *Psammobatis spinosissimus*. Photograph of holotype, 248 mm.

PLATE III.

- Fig. 1. *Dasyatis brevis*. Specimen from Inez Bay, Lower California, 1,257 mm.
 Fig. 2. *Urobotis concentricus*. Specimen from Port Guatulco, Mexico, 385 mm.

PLATE IV.

- Fig. 1. *Manta lucasana*. Upper surface of holotype, 1,035 mm. across disk.
 Fig. 2. *Manta hamiltoni*. Enlargement of motion-picture film of 18-foot-wide female, taken at Narborough Island, Galápagos Islands, showing indistinctly the pale shoulder-patches.

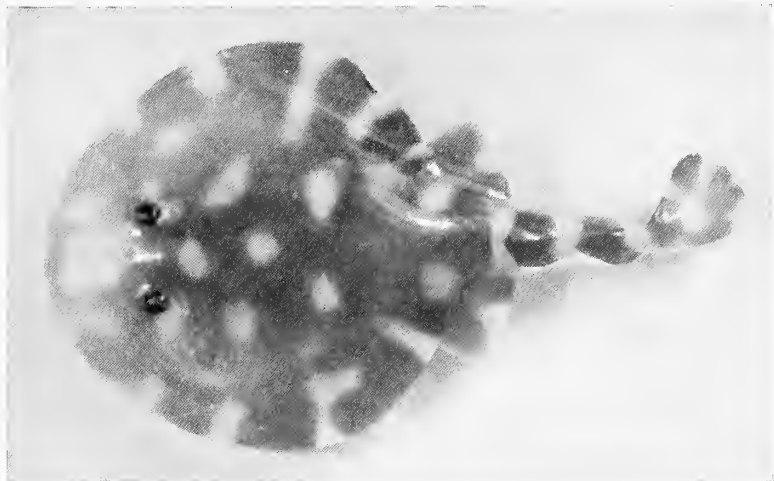


FIG. 1.

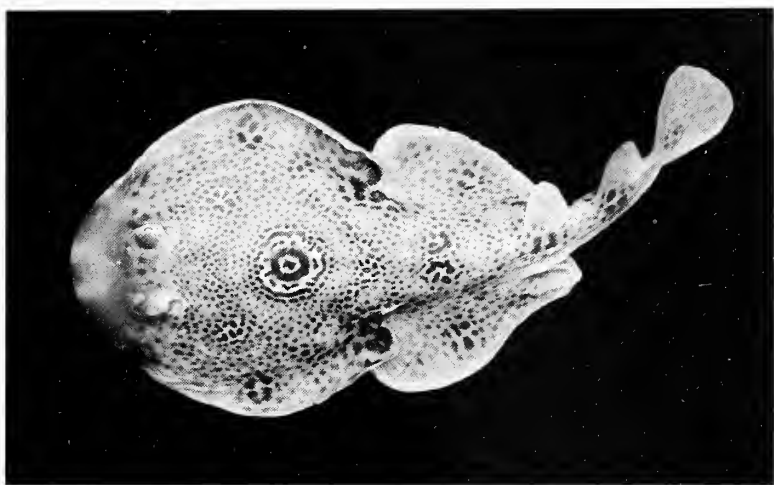


FIG. 2.

FISHES FROM THE TROPICAL EASTERN PACIFIC. PART 3.
RAYS, MANTAS, AND CHIMAERAS.



FIG. 1.



FIG. 2.

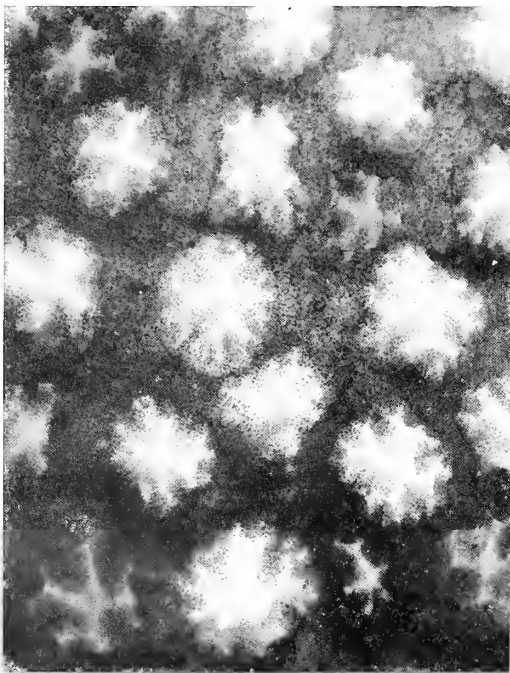


FIG. 3.



FIG. 4.



FIG. 1.

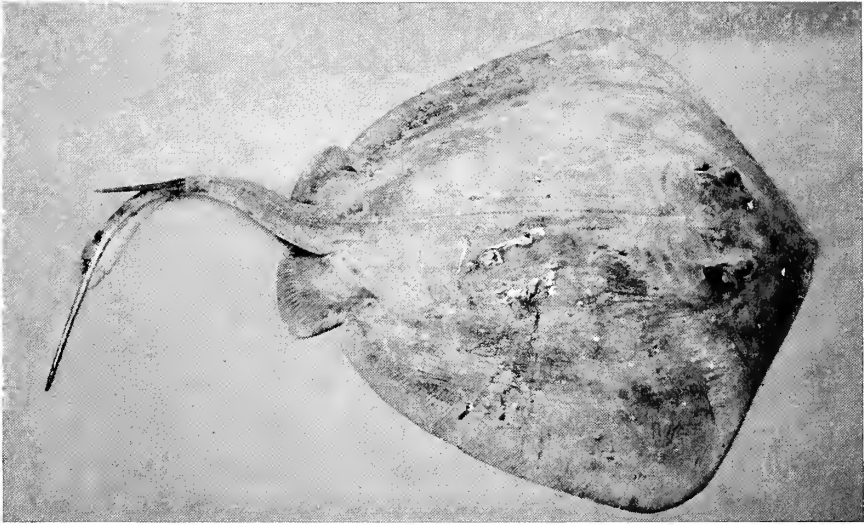


FIG. 2.

FISHES FROM THE TROPICAL EASTERN PACIFIC. PART 3.
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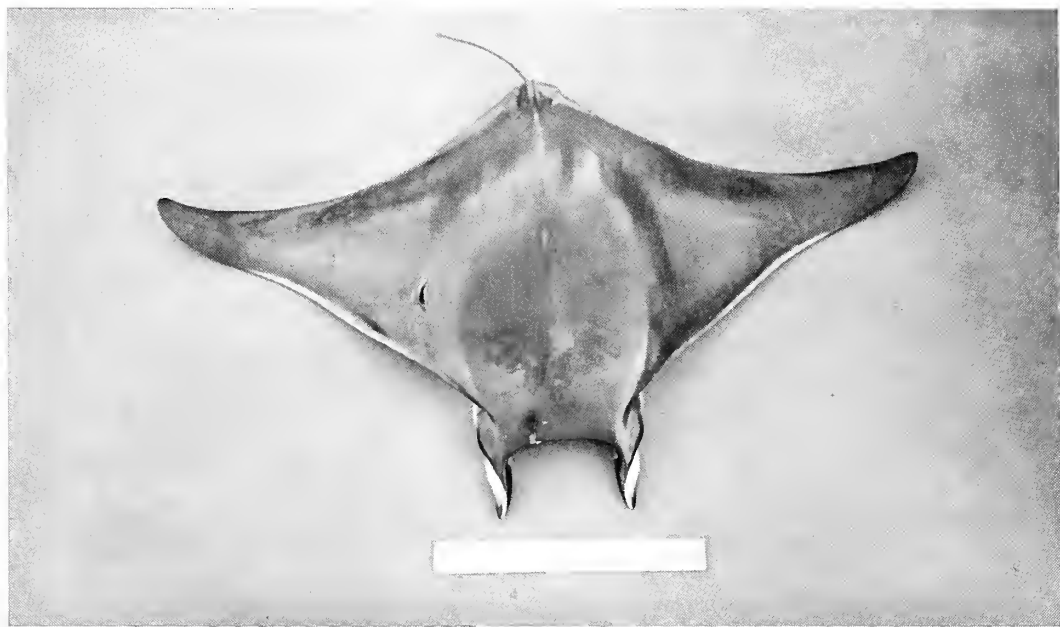


FIG. 1.



FIG. 2.

FISHES FROM THE TROPICAL EASTERN PACIFIC. PART 3.
RAYS, MANTAS, AND CHIMAERAS.

27.

Erotylidae of Kartabo, Bartica District, British Guiana. (Coleoptera).¹

C. H. CURRAN

(Plate I; Text-figure 1).

[During the eight years of occupancy, by the Department of Tropical Research, of the New York Zoological Society's Station at Kartabo, British Guiana, extensive collections of insects were made. These were all taken in the quarter-mile area under intensive study—what may be called the Guiana Jungle-zone. Details and a general summary of this area may be found in "Studies of a Tropical Jungle," *Zoologica*, VI, No. 1.]

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INTRODUCTION.

The Erotylidae usually form a conspicuous part of any collection of tropical beetles and are fairly well represented in the collections made at the Tropical Research Station of the New York Zoological Society at Kartabo, British Guiana. Inasmuch as a large number of species belonging

¹ Contribution No. 631, Department of Tropical Research, New York Zoological Society.

to the family have been described from French Guiana, material from this region is of particular interest since the specimens generally agree perfectly with the original descriptions while those from other regions may show some variations and it is often difficult to identify specimens.

The family is composed of beetles of diverse form, often brilliantly colored, and resembling members of various other families, particularly the Chrysomelidae, Coccinellidae and Tenebrionidae both in general form and color. Many of the species have color patterns that are almost identical with members of one or more of these families.

The collection made at Kartabo contains twenty-five species, five of them apparently new to science, belonging to thirteen genera. Almost all of the material was collected in the quarter-mile of jungle in which intensive studies were carried on by Dr. Wm. Beebe and his associates during the 1920's. While many more species undoubtedly occur in the area studied, the collection is an excellent cross-section of the family occurring in any given region of the humid American tropics. Since the occurrence of the beetles is dependent upon fungus, upon which they feed, and on which they sometimes occur in large numbers, the beginning of and end of the rainy season usually finds the beetles most abundant. Dr. Beebe tells me that every beetle in this collection, with the exception of three individuals, was taken on fungus on the bark of jungle trees.

The illustrations are the work of Mr. Donald Greame-Kelley.

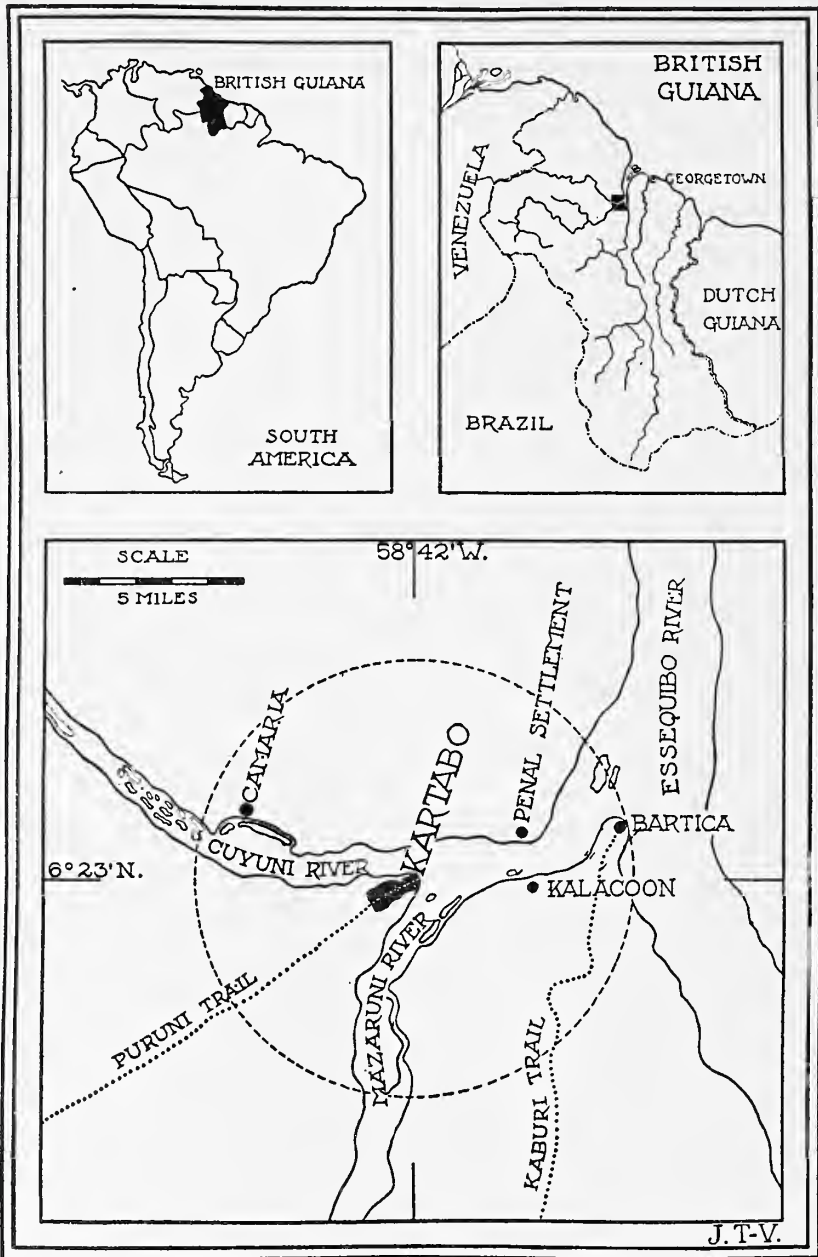
The types of new species have been deposited in the collection of the Department of Tropical Research, New York Zoological Park.

Omoiotelus Hope.

Hope, 1841, *Rev. Ent.*, p. 112.

Homoeotelus Erichson, 1847, *Wiegmann Arch. f. Naturg.*, XIII, p. 177.

The species belonging to this genus are readily recognized by the long, slender legs and antennae. They are very similar in appearance and difficult



Text-figure 1.

British Guiana Tropical Research Station of the New York Zoological Society.
The circle represents a radius of six miles.

to identify. The spelling *Homocotelus* has been used since Erichson used the emended spelling in 1847.

***Omoiotelus pallidus* Olivier.**

Erotylus pallidus Olivier, 1791, Encycl. Meth., VI, p. 436.

Three specimens from Kartabo, July 11, 1922, and No. 615.

***Ægithus* Fabricius.**

The collection contains one species belonging to the group having large black punctures.

***Ægithus punctatissimus* Fabricius.**

Erotylus punctatissimus Fabricius, 1775, Syst. Ent., p. 123.

Ægithus separandus Crotch, 1876, Cist. Ent., I, p. 490.

A single specimen, Kartabo, May 3, 1924.

In an excellent series of this species from the upper Amazon there are specimens that agree with the description of *separandus*, described from Ecuador, and I do not think that the name can be retained. There is a good deal of variation in the size and number of spots in this species as well as in *burmeisteri* Lacordaire which differs in having the hypopleura mostly yellowish.

Erotylus Fabricius.

One species is contained in the collection. The genus may be distinguished from its near allies by the presence of three carina on the upper surface of the tibiae and the absence of a basal impressed margin on the pronotum, which has several deep depressions.

Erotylus variegatus Fabricius.

Fabricius, 1781, Sp. Ins., I, p. 157.

There are two specimens from Kartabo, August 20 and 28, 1920.

Hypselonotus Hope.

Hypselonotus Hope, 1841, Rev. Ent., p. 111.

Cypherotylus Crotch, 1873, Trans. Amer. Ent. Soc., p. 358.

It is quite possible that both these names may be used for two groups that have generally been placed in *Cypherotylus*. *Hypselonotus* was proposed for the group in which the elytra are produced upward, forming a keel or hump, while *Cypherotylus* has the elytra evenly convex when viewed from behind, there being no indication of a "keel."

The collection contains what may prove to be four species that would belong in *Hypselonotus* s. s., but inasmuch as the genus is very badly in need of revision and it is very difficult to determine the specific limits without series of the species, I make no attempt to name three of them at the present time, but present a key for their separation.

TABLE OF SPECIES.

- 1. Elytra with a black fascia, sometimes interrupted on each elytron, near the middle. 2.
- Elytra with only the apex broadly black. .sp. A.
- 2. The median black fascia is interrupted. 3.
- The median black fascia is entire. sp. B.
- 3. The median black fascia is very narrowly interrupted on each elytron, the black punctures sparse. sp. C.
- The median black fascia is very broadly interrupted, the black punctures moderately numerous and partly in rows. *gibbosus* Linnaeus.

Hypselonotus gibbosus Linnaeus.

——— *gibbosus* Linnaeus, 1763, Cent, Ins., p. 10.

Four specimens, Kartabo, March 10 and May 2, 1924, and Kalacoon, 1916.

This is the species that has generally been determined as *gibbosus* Linnaeus and it seems advisable to accept the determination. It is recorded from as far north as Nicaragua and I have before me a series from the upper Amazon.

Hypselonotus sp.A; sp.B; sp.C.

The three species included in the above key do not agree with any others I have seen but it is possible that one or more of them are described.

Scaphidomorphus Hope.

One of the two described species is represented in the collection.

Scaphidomorphus quinquepunctatus Fabricius.

Erotylus 5-punctatus Fabricius, 1775, Syst. Ent., p. 123.

One specimen, September 7, 1920.

Up to the present time the species is recorded only from Cayenne but I have examples from Para, Brazil, and a number from various localities in British Guiana.

Prepopharus Erichson.

Three species have been recorded from the Guianas, two of which are represented in the collection along with an undescribed form. The following key will separate them.

TABLE OF SPECIES.

- 1. Prothorax brownish; femora reddish
opalizinus Lacordaire.
Prothorax normally black or reddish, if brownish the femora black. 2.
- 2. Prothorax black, legs black. *notatus* Olivier.
Prothorax reddish or yellowish, sometimes with black spots. 3.
- 3. Prothorax without distinct blackish spots; elytra each with eight obscure dark spots
obscurior, sp. nov.
Prothorax and elytra with shining black markings
undatus Fabricius.

Prepopharus notatus Olivier.

Erotylus notatus Olivier, 1791, Encycl. Meth., VI, p. 435.

This is the type of the genus and is a large species, black, the elytra each with a pair of orange basal spots and a wide median yellow fascia containing two rows of black spots. In one of the two specimens from Kalacoon, 1916, the pronotum is dark brown.

Prepopharus undatus Fabricius.

Erotylus undatus Fabricius, 1801, Syst. Eleuth., p. 8.

Shining rusty-reddish with black markings. The pronotum bears either four or six black spots, each elytron typically with a row of three black spots near the base and two wavy black bands.

One specimen from Kartabo, No. 20893.

This species is quite variable and a number of names have been applied to it. It has been recorded only from northern South America.

Prepopharus obscurior, sp. nov.

Moderately shining pale ferruginous, the elytra with obscure blackish spots. Length, 7 mm.

Female.?—Head unicolorous, the front with numerous fine punctures; antennae black, the

basal four segments reddish. Thorax unicolorous, with fine punctures. Legs reddish, the intermediate tarsal segments somewhat darkened laterally; middle coxal line moderately long. Elytra each with eight obscure blackish spots, three of which are quite large, two close to the suture, one at the basal third and one slightly behind the middle, the third behind the humeri; a small basal spot near the middle; the sublateral spot behind the humeral spot is small, the other three are situated: one behind the inner end of the humeral spot, one sublaterally just behind the middle and one in the middle just in front of the apical fourth. There are seven rows of isolated punctures which become obsolete at the apical fourth, the surface otherwise with some extremely fine punctures so that it appears slightly roughened. The inner margin of the epipleura is black on more than the basal half.

Holotype.—Kartabo, May 22.

This species is readily distinguished from all others by the weak elytral spots and reddish legs. The spots are not clearly seen without strong light. It is probable that they may be conspicuous in some specimens and perhaps they may be entirely absent in other examples.

Zonarius Hope.

I present a key, based on descriptions, to the species placed in this genus. I am unable to place two species in the collections before me but they may prove to be no more than color varieties of described forms.

TABLE OF SPECIES.

1. Prothorax wholly black above..... 9.
Prothorax partly reddish or yellowish..... 2.
2. Prothorax reddish above, rarely with weak dark spots; elytra with numerous punctures (Amazon).....*convexus* Crotch.
Prothorax black and pale or pale with black spots..... 3.
3. Prothorax pale with five or eight black spots. 4.
Prothorax differently colored..... 6.
4. Prothorax with eight black spots in two transverse rows..... 5.
Prothorax with five black spots; elytra with numerous punctures (Guiana, Amazon)
cinctus Herbst.
5. Elytra with numerous punctures; epimeron black except at base (Amazon).....sp.
Elytral intervals smooth; epimeron wholly reddish (Bolivia).....*nigrotibialis* Demay.
6. Prothorax black on the base, reddish or yellowish in front..... 8.
Prothorax black with reddish markings... 7.
7. Prothorax black, the sides yellowish or reddish (Amazon).....*convexiusculus* Crotch.
Prothorax black, the anterior angles and a discal spot reddish (Amazon) *erythrogonus* Crotch.
8. Elytra yellow with five black spots (Colombia)
fractus Crotch.
Elytra with the black median fascia entire (S. Amer., C. Amer.).....*zebra* Fabricius.
9. Abdomen reddish or yellowish..... 11.
Abdomen wholly black..... 10.
10. Basal yellow spot on each elytron broadly connected with the first yellow fascia (Guiana)
xanthomelas Lacordaire.

- Basal yellow spot isolated (Guiana)
indicus Herbst.
11. Elytra with numerous punctures over most of the surface..... 12.
Elytra with very few punctures on the intervals except laterally..... 13.
 12. Each elytron with a golden fascia near the middle (in addition to other markings)... 16.
Each elytron with two yellow spots near the middle (Ecuador).....*buckleyi* Crotch.
 13. Abdomen wholly pale or practically so.... 14.
Abdomen with transverse blackish spots on each side (Mexico).....*cacicus* Lacordaire.
 14. Each elytron with five black spots (Brazil)
militaris Germar.
Each elytron with a transverse median black fascia..... 15.
 15. Epimeron yellow (Panama).....sp.
Epimeron mostly black
(*Z. trizonatus* Germar and *hybridus* Erichson come here)
 16. Head reddish in front (Ecuador)
rugipunctatus Crotch.
Head black..... 17.
 17. Two black fasciae of about equal width, the apex broadly black (Brazil)
pergrinus Lacordaire.
Anterior black fasciae narrow, the median one broad (Colombia) *nigrotaeniatus* Lacordaire.

Zonarius xanthomelas Lacordaire.

Lacordaire, 1842, Mon. Erot., p. 469.

Two specimens, Kartabo, June 6, 1919, and No. 391.

This has been placed as a synonym of *indicus* Herbst but the name may be retained until the genus has been thoroughly studied.

Brachysphoenus Lacordaire.

This genus contains more than two hundred species of diverse form. A number of genera have been proposed, some of them undoubtedly valid, for various groups, but it is impossible to determine the distribution and relationship of the various forms without an abundance of material. Although many species have been described from the Guianas, only two are represented in the collection.

Brachysphoenus moniliferus Guerin.

Mycotretus moniliferus Guerin, 1841, *Rev. Zool.*, p. 155.

A single specimen, Kartabo, July 7, 1920.

Lacordaire places this species in the subgenus *Megaprotus*.

Brachysphoenus ardens, sp. nov.

Shining black, the elytra with two laterally connected orange fasciae, one basal, the other at the apical third. Length, 8 mm.

Female.—Shining black, the under surface brownish-black, the head somewhat reddish in front, with fine punctures; antennae black, the two basal segments reddish, the apical segment reddish-yellow. Pronotum finely punctured, the prosternum carinate anteriorly. Tarsi dark ferruginous. No coxal lines. Elytra with basal and postmedian orange fasciae narrowly interrupted

at the suture and broadly connected along the lateral margin, the basal fascia narrowed by two black projections, the outer one the larger, the lateral orange stripe triangularly broadened behind the humeri and extending along the sides of the posterior black band to the apical seventh of the elytron; posterior pale fascia slightly oblique and weakly bidenticulate. There are seven rows of rather conspicuous punctures beginning at the basal sixth and extending to the posterior border of the first black band; epipleura orange except apically.

Holotype.—female, Kartabo, April 10, 1924.

This species agrees in almost all respects with *B. duplicatus* Lacordaire, from Colombia, but *duplicatus* lacks the rows of punctures on the elytra, with the exception of the first which is feebly indicated.

***Lybas* Lacordaire.**

The following key will separate the species of *Lybas* in which the elytra are bicolored and the scutellum is only narrowly covered at the base by the pronotum.

TABLE OF SPECIES.

1. Pronotum unicolorous or nearly so, often pale laterally..... 2.
Pronotum black and yellow or reddish..... 5.
2. Elytra each with large triangular yellow spot at the base..... 3.
Elytra each with the base narrowly yellow, the humeri sometimes black..... 4.
3. Short oval, the legs yellowish-red, the epipleura yellow basally (Guiana)
mycetophilus Lacordaire.
Oval, the legs reddish-brown, the epipleura not yellow basally (Guiana). *seminulus* Lacordaire.
4. Oval, blood-red (Guiana)..... *axilaris* Lacordaire.
Elongate oval, brownish-black (maroon) (Guiana)..... *pulicarius* Lacordaire.
5. Pronotum with two black spots on the yellow ground on each side (Guiana)
normalis Lacordaire.
Pronotum with at most one black spot on each side..... 6.
6. Pronotum without black spots in the reddish ground..... 9.
Pronotum with black spot in the pale ground..... 7.
7. Pronotum reddish on the sides..... 8.
Pronotum pale yellowish on the sides (Colombia)..... *chlamydophorus* Lacordaire.
8. The black band on the elytra extends back almost to the middle (Colombia) *calidus* Lacordaire.
The black band is represented by a small basal triangle on the outer half of the base (Guiana)..... *triangularis*, n. sp.
9. Elytra each with basal transverse yellow triangle followed by black spot (Guiana)
guianicus, n. sp.
Elytra black on basal three-fourths except at the side (Peru)..... *dorsalis* Gorham.

***Lybas triangularis*, sp. nov.**

Dark rusty-reddish, the prothorax, head and legs mostly black; elytra with black basal triangle. Length, 6.5 mm.

Female.?—Head black, reddish on the sides

below and obscurely reddish in front, the clypeus reddish-yellow; antennae obscure reddish, the club brown; frontal punctures large and numerous, almost absent in the middle posteriorly. Prothorax black, the sides very broadly reddish-yellow and bearing a small black spot on each side above, the punctures large but not conspicuous, almost evenly distributed; there is a strong indication of a large dull reddish spot in the black ground immediately in front of the scutellum and a small reddish area outside the coxae. Coxae dark reddish, the anterior pair more or less brown; femora and tibiae black, the latter with the apices somewhat reddish, the middle pair reddish on almost the apical half; tarsi reddish. Scutellum shining black; elytra dark rusty-reddish, each with a moderately small, subtriangular black spot covering the humeri, narrowly separated from the lateral margin, extending to a little behind the humeral area and narrowly produced inward along the base but not clearly reaching the scutellum. There are eight rows of deeply impressed punctures, the outer one obsolete for one-sixth its length in the middle and all but the inner and outer ones united posteriorly with another row of punctures, some uniting with two rows, the second and seventh uniting. The epaulet is narrowly margined on both sides with reddish-brown.

Holotype.—Kartabo, April 12, 1922.

The single specimen appears to be a female and differs in color from any of the described species. In *calidus* the elytra are black on almost the basal half except on the very narrow sides, while in *dorsalis* they are black on almost the basal two-thirds and the pronotum lacks the lateral black spots.

***Lybas guianacus*, sp. nov.**

Ferruginous, the elytra with black and yellow markings on the basal half; pronotum black in the middle. Length, 6 mm.

Female.—Head ferruginous, with a broad, darker (perhaps sometimes blackish) fascia in front of the vertex, the punctures moderately numerous and rather fine. Palpi reddish-yellow. Antennae ferruginous, the apical six segments brown or blackish. Pronotum with the median three-fifths black, the sides, rather broadly connected anteriorly, broadly reddish, the very narrow border blackish. Punctures rather fine and not very numerous. Legs reddish, the bases of the tibiae narrowly darker. Elytra shining rusty-reddish, the base very broadly yellowish on the outer three-fourths, the fascia thus formed is very broadly interrupted in the middle and is broadly widened inside the lateral margins; behind the yellow fascia is a pair of large contiguous black spots forming an irregular oblique black fascia bordering the yellow band on its outer three-fourths and conspicuously separated from the lateral margin. There is a small black spot on the base of each elytron contiguous to the scutellum and the very narrow lateral margin is blackish basally, becoming ferruginous behind

the middle. There are seven rows of rather deep isolated punctures all extending to near the apex, those on the reddish spots underlaid with darker spots, but, as in other species it is probable that the darker spots may be absent.

Holotype.—Female, Kartabo, April 10, 1924.

This species should be readily recognized by the black and yellow marked elytra and the absence of isolated black spots on the pronotum.

Phricobacis Crotch.

The genus contains eight described species to which another is now added. The key is based on descriptions, the study of which indicates that there are probably only four or five valid species in the genus.

TABLE OF SPECIES.

1. Pronotum unicolorous..... 5.
Pronotum pale with dark markings..... 2.
2. Pronotum with four or six black or brown spots..... 3.
Pronotum with eight reddish-brown spots (Amazon).....*pulcher* Crotch.
3. Reddish-ferruginous, the suture and margin yellowish; antennae, tibiae and tarsi black (Peru) (*arduus* Erickson)..... 4.
Yellowish-ferruginous, the elytra reddish-yellow with ferruginous margins; antennae, tibiae and tarsi black (Guiana).....*navicularis* Lacordaire.
4. Pronotum with six black spots.*arduus* Erickson.
Pronotum with four black spots basally
var. *hepaticus* Kirsch.
5. Elytra chiefly black..... 6.
Elytra reddish to yellowish..... 8.
6. Elytra black, the margins reddish..... 7.
Elytra with three yellow fasciae (one basal) and the apex reddish (Guiana).....*beebei*, n. sp.
7. Apex of elytra rather broadly reddish (Amazon)
rufolimbatus Crotch.
Apex of elytra not broadly reddish (Bolivia)
marginatus Guerin.
8. Apices of the femora black (Brazil)
ratzburgii Lacordaire.
9. Femora reddish..... 9.
9. "Oblong-oval"; suture not paler (Bolivia)
hopei Guerin.
"Oblong"; suture yellow (Amazon)
batesi Crotch.

Phricobacis beebei, sp. nov.

Differs from all the described species by having the elytra fasciate. Length, 9 mm.

Female.—Pale rusty-reddish or ferruginous, the elytra dark brown, reddish and yellow. Apical segment of the maxillary palpi four times as wide as long; antennae with the club blackish. Front with large punctures which are shallow and sparse posteriorly, more numerous and deeper anteriorly. Prothorax reddish-yellow toward the sides but the margin is ferruginous, the punctures large and more or less confluent laterally, much smaller and rather sparse on the disc; no coxal lines. Scutellum longer than wide. Elytra black; the suture, narrow lateral margin and the rather broad apex pale rusty-reddish; the inner edge of the yellow epipleura of the same color; the moderately broad base and lateral margins and two fasciae yellowish; a narrow yellow fascia

extends across the elytra near the middle while another about twice as wide is situated at the apical fourth, being separated from the reddish apex on each elytron by a transverse blackish spot. The punctures are large and deep, a few confluent, generally irregularly placed but some form regular rows, particularly those toward the inner edges of each elytron.

Holotype.—Female, Kartabo, August 1, 1922.

Mycotretus Chevrolat.

The collection contains five species belonging to this genus, separable as follows:

TABLE OF SPECIES.

1. Elytra uniformly reddish..... 2.
Elytra yellowish with black spots..... 4.
2. Palpi very large, the third segment more than three times as wide as long..... 3.
Palpi smaller, twice as wide as long
pygmaeus Lacordaire.
3. Short oval, the apical four segments of the antennae black.....*coccineus* Lacordaire.
Elongate, the apical six or seven segments of the antennae black.....*durius* Lacordaire.
4. Pronotum with a median basal and apical black spot.....*dorsonotatus* Lacordaire.
Pronotum with 8 black spots, the basal three united.....*maculatus* Olivier.

Mycotretus coccineus Lacordaire.

Lybas coccineus Lacordaire, 1842, Mon. Erot., p. 239.

? *M. sanguinosus* Crotch, 1876, Cist. Ent., I, p. 458.

Nine specimens from Kartabo, June 1 to 24, 1924.

M. coccineus was described from Rio de Janeiro, *sanguinosus* from New Grenada. There is nothing in the descriptions by which the two can be distinguished and I believe both names apply to the same species. If there are two species concerned *sanguinosus* would probably apply to the specimens before me. It has been recorded also from Panama and Costa Rica.

Mycotretus pygmaeus Lacordaire.

Lacordaire, 1842, Mon. Erot., p. 156.

The collection contains a single specimen collected on March 21, 1922. It is wholly shining reddish except the apical six segments of the antennae which are black.

Mycotretus dorsonotatus Lacordaire.

Lacordaire, 1842, Mon. Erot., p. 151.

One specimen, Kartabo, August 23, 1922.

This specimen does not wholly agree with the description given by Lacordaire but I believe it is the same species, differing only in a slight modification of the color pattern. The species is rusty-reddish, with the following black spots: one on the front of the pronotum in the middle and another adjacent to the mostly black scutellum, one on each side of the under surface of the pronotum and a paired black spot near the middle of each elytron. The elytra have broad

alternate rusty reddish-yellow and yellow vittae; the inner dark stripe is along the suture while the broad lateral border is pale. In addition to the paired black spots there are darker spots on the dark vittae near the base and also near their apices, and the punctures are darkened. The antennae are blackish with the two basal segments reddish.

The color of the elytra lends itself readily to considerable variation and I suspect that many color varieties occur.

***Mycotretus maculatus* Olivier.**

Erotylus maculatus Olivier, Encycl. Meth., VI, p. 436.

Two specimens, Kartabo, May 10, 22, 1924.

***Mycotretus durius* Lacordaire.**

Lacordaire, 1842, Mon. Erot., p. 161.

One specimen, Kartabo, May 25, 1924. No. 24716.

The specimen is almost unicolorous and agrees well with the description. I have seen no other unicolorous species that closely approaches it.

***Pselaphacus* Percheron.**

Of the twenty-seven species assigned to this genus two are represented in the collection.

***Pselaphacus giganteus* Germar.**

Triplax giganteus Germar, 1824, Ins. Sp. Nov., p. 615; Lacordaire, Mon. Erot., p. 76.

Twenty-one specimens from Kartabo: April 29, 1920; August 28, 1920; September 16, 1922; April 20, 1924; May 25, June 20, 21 and 23, and Nos. 24708-14 and 24966-67.

This species is recorded only from the Guianas. The color of the elytra varies from dull dark reddish to pale orange.

***Pselaphacus signatus* Guerin.**

Guerin, 1841, Rev. Zool., p. 158.

Nine specimens from Kartabo: March 24, 26, 1924; May 25, June 21, 22, and Nos. 24715, 24718 and 24968.

In the series the color of the elytra varies from dark reddish to pale orange and there is some variation in the size of the black spots.

This species is widely distributed in northern South America and in Central America.

***Megischyrus catenatus* Crotch.**

Crotch, 1876, Cist. Ent., 1, p. 424.

A single specimen, May 20, 1924.

This species is somewhat smaller than *catenulatus* Lacordaire and lacks the lateral reddish vitta on the anterior half of the elytra. It has been recorded from Ecuador and the Amazon region.

EXPLANATION OF THE PLATE.

PLATE I.

- Fig. 1. *Hypsilonotus* species A. × 2.
Fig. 2. *Hypsilonotus* species B. × 2.
Fig. 3. *Hypsilonotus* species C. × 2.
Fig. 4. *Prepopharus obscurior* sp. nov. × 5.
Fig. 5. *Brachysphoenus ardens* sp. nov. × 5.
Fig. 6. *Lybas triangularis* sp. nov. × 5.
Fig. 7. *Lybas guianacus* sp. nov. × 5.
Fig. 8. *Phricobacis becbei* sp. nov. × 5.

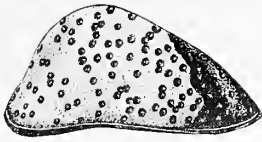


Fig. 1



Fig. 2

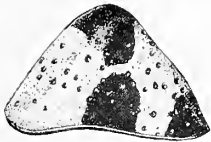


Fig. 3

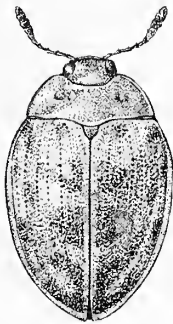


Fig. 4

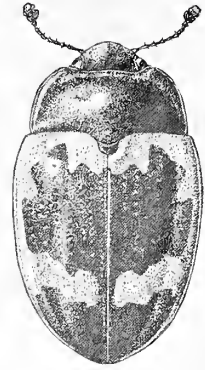


Fig. 5

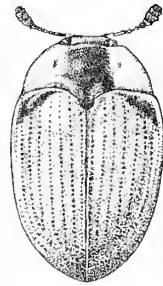


Fig. 6

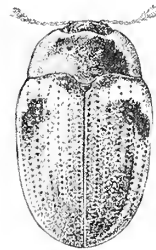


Fig. 7

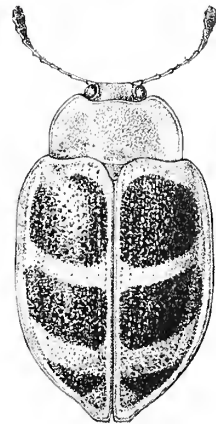


Fig. 8



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28.

Further Studies on the Light Sensitivity and Behavior of the Mexican Blind Characin.

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&

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(Plate I; Text-figures 1 & 2).

INTRODUCTION.

It has been shown by Breder & Gresser (1941) that the blind individuals of the Mexican Characin *Anoptichthys-Astyanax* series are light sensitive. This was made evident by their behavior in a gradient trough in which they showed themselves to be slightly but clearly light negative. No attempt had been made at the time that report was prepared to delimit the mechanism of this discriminatory power. The cystic form of the vestigial remnant of eye structure and its heavy investing pigment layer seemed to preclude its use as an organ of light detection, Gresser & Breder (1939) and Breder & Gresser (1941).

EXPERIMENTS.

As one step toward understanding this mechanism of light perception a normal blind specimen was selected, and the vestigial eye structures were removed. Healing was rapid and satisfactory and no gross differences could be detected in its behavior.

Two tanks were employed, each with one-half light and one-half dark as described in Breder & Gresser (1941). Into one was placed a normal blind fish as a control and in the other the experimental fish. As in the earlier paper, counts were made of the frequency of appearance of the fish in the lighted halves of the tanks. The data obtained, which covered nearly a month, are given in Table I. This table indicates clearly that the experimental fish showed no bias to one compartment, the actual distribution being within 0.29 — of the expectation. The

control, on the other hand, agreed well with the experiments previously reported, and fell to 13.71+ of expectation; showing that much bias to the dark half of the tank. Expressed in terms of percentage of random expectation with 100% representing pure randomness, above it light positiveness and below it light negativeness, the following figures represent the situation:

Experimental	100.58%
Control	72.58%

It is thus evident that the light detection of these fishes is lodged in some retention of function in the optical vesicle, despite its histological appearances to the contrary. The test fish, at this writing, is still living and apparently not in the least inconvenienced by its loss of ability to detect light. It cannot be separated from the others on a basis of behavior except by some formal procedure as above outlined. In previous papers concerning the ocular morphology of these blind fish, various types of undeveloped and mal-developed eyes were shown. Based on histological appearances, very little if any function was attributed to any eye of the cystic type even if a few scattered retinal elements were present. It was understandable that eyes architecturally intact but of comparatively microphthalmic proportions could be serviceable under restricted conditions and that anophthalmic vestiges predicated complete blindness. The present study involving individuals with defective ocular structures but in which some, if sparse, rods and cones are present leads to the inescapable conclusion that there is some subservance to light sensation. However, it remains for further behavior experi-

ments followed by studies of histological preparations to determine the least number of retinal elements necessary for light sensation.

If the percentage of light avoidance of the control be compared with those reported by Breder & Gresser (1941), it is found that the present value of 72+%, compared with 62+% of its earlier tested tank mates and with 80-% of the larger fish taken directly from La Cueva Chica, places this fish roughly half way between those two groups. In reference to the latter values the following was stated in the earlier paper. "This difference of 17% may actually be significant. The cave fish were larger than the others and possibly overlying tissues of greater consequent thickness may account for the difference, or it may be that there is an increased avoidance to light in subsequent generations." Since those experiments were made the fishes reared in light for five generations (62+%) have grown so as to just about half close the size difference between them and the individuals from the cave (80-%). Consequently the lessened avoidance to light is about proportional to their growth (72+%). This suggests strongly that of the two quoted alternatives the first would seem to be the true one. In other words, it seems clearly indicated that the amount of overlying tissue determines to a considerable extent the reactivity of these fish to light. Further studies on much smaller specimens would go far to establish this view.

In order to better understand the normal unrestricted behavior of these fishes, an out-door pool was established in which approximately one-half was darkened so as to form a "cave" into which entry could be made from under water only. The entrance was provided with a light trap so that a true cave-like darkness could be obtained. This portion of the pool was roofed over and buried under about six inches of soil in which trailing vines were planted. The general arrangement and details of construction are given in Text-figure 2 while Plate I shows how the finished structure appeared.

Both blind "5th generation" and tank-raised normal river fish were placed in this pool and allowed to act according to their normal instincts. The trap door in the roof of the "cave" was padlocked and not opened until the termination of the experiments. Food was admitted to the "cave" through a small hole which was otherwise kept corked. More food was placed in the cave than in the lighted portion in order to prevent any possible bias to the outside based on hunger. Water was introduced only to make up for evaporation. This drained from another pool into the darkened portion through a light trap of loose rocks and gravel. From here it flowed through the cave and out into the lighted portion, simulating so far as possible the conditions in La Cueva Chica (see Bridges, 1940). Water lillies and *Nitella* grew in the lighted portion. In this brightly sunlit pool shade was provided by an offset in the cave wall from which the lillies grew

TABLE I.

Exp. No.	Date 1941	Hour	Number of observations in light	
			Fish No. 33	Fish No. 34
1	5/28	4:00 p.m.	48	32
2	5/29	9:30 a.m.	47	40*
3	5/29	4:30 p.m.	51	20
4	6/2	10:40 a.m.	36	39
5	6/2	4:30 p.m.	54	19
6	6/3	9:00 a.m.	53	27
7	6/3	4:15 p.m.	8	44
8	6/3	—	32	36
9	6/4	8:40 a.m.	56	35
10	6/4	4:45 p.m.	56	36
11	6/5	9:25 a.m.	65	35
12	6/5	4:25 p.m.	57	37
13	6/6	9:30 a.m.	64	27
14	6/6	4:45 p.m.	60	46
15	6/7	10:30 a.m.	55	34
16	6/7	4:55 p.m.	58	34
17	6/8	11:15 a.m.	55	26
18	6/8	5:00 p.m.	50	29
19	6/9	10:00 a.m.	60	47
20	6/9	4:10 p.m.	50	40
21	6/10	—	36	37
22	6/10	—	58	33
23	7/1	9:45 a.m.	44	46
24	7/1	4:45 p.m.	38	34
25	7/2	10:15 a.m.	51	43
26	7/2	4:30 p.m.	39	37
27	7/3	9:45 a.m.	52	34
28	7/3	4:45 p.m.	62	50
29	7/4	11:00 a.m.	72	39
30	7/4	3:30 p.m.	56	37
31	7/5	11:00 a.m.	63	44
32	7/5	3:00 p.m.	60	57
33	7/6	11:25 a.m.	38	34
34	7/6	4:50 p.m.	32	34
35	7/7	10:20 a.m.	44	40
36	7/7	2:30 p.m.	10	41
37	7/8	10:30 a.m.	32	28
38	7/8	2:30 p.m.	23	18
39	7/9	9:00 a.m.	74	44
40	7/9	3:30 p.m.	54	40
41	7/10	9:30 a.m.	73	46
42	7/10	—	86	25
			2112	1524
		Average	50.29—	36.29—
		Maximum	65	74
		Minimum	8	10
			% of Expectation	
		Average	100.58—	72.58—
		Maximum	130	142
		Minimum	16	20

* Each experiment represents 100 notations at 5-second intervals except the figure marked which was 75 and recalculated. There were 30 notations in light of the 75. Most of the actual readings were made by Mr. Max Recher.

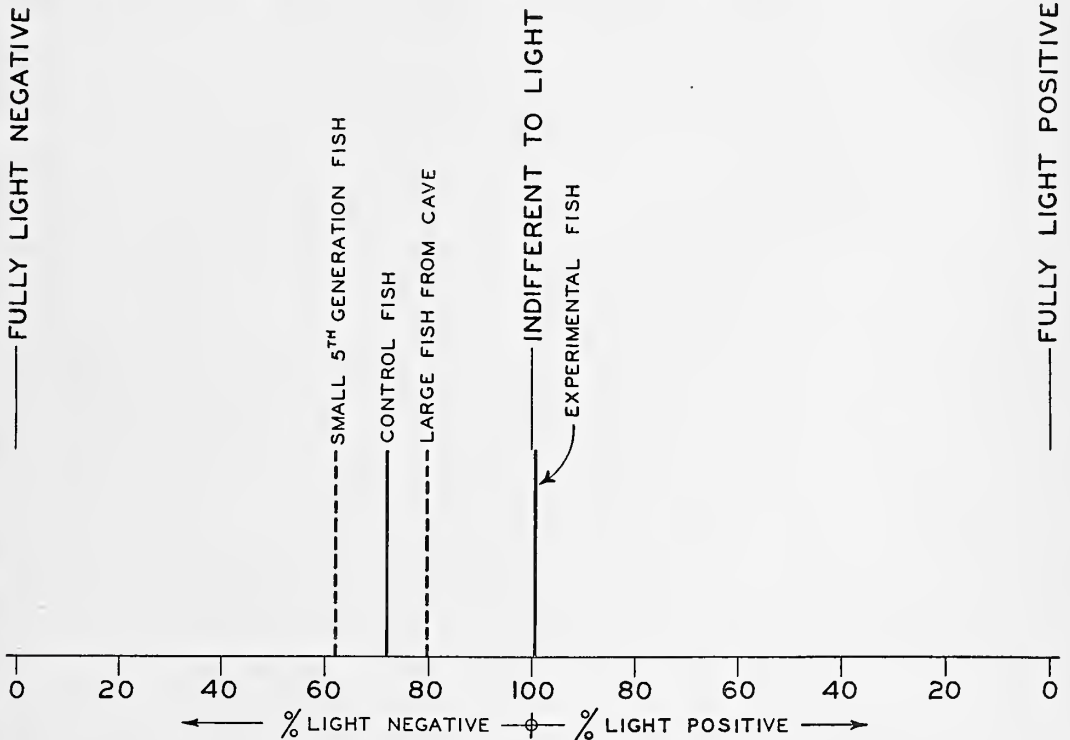
and which was further shaded by a large *Cyperus* plant so that fishes would not necessarily be driven into the cave for the mere want of shade. As noted above, the water used drained from another well-seasoned pool which was being used for other fishes. This pool, shown in connection with other matters by Breder (1939 and 1940) and described in detail therein, drained into the new blind fish pool from its northeast corner.

The latter had been originally built for another purpose, see Schlaifer & Breder (1941).

Data on temperature differentials and similar matters are given in chronological order in Table II. The fishes were all introduced into the lighted portion of the pool. Initially two blind fishes were placed in the pool to test if they could stand the early spring temperatures. In less than twenty-four hours these fish found the cave entrance and spent much time in the cave from then on, but wandered in and out at will. Apparently it took no longer time than this for them to learn their way about in the area of this pool for after the first day it was noted that they hardly ever struck objects and they would go in and out the somewhat tortuous entrance touching nothing. Since they show no evidence of distance reception, as noted by Breder & Gresser (1941) it would appear that they can satisfactorily learn the terrain of about one hundred and fifty square feet of area, which the pool covers, in that time.

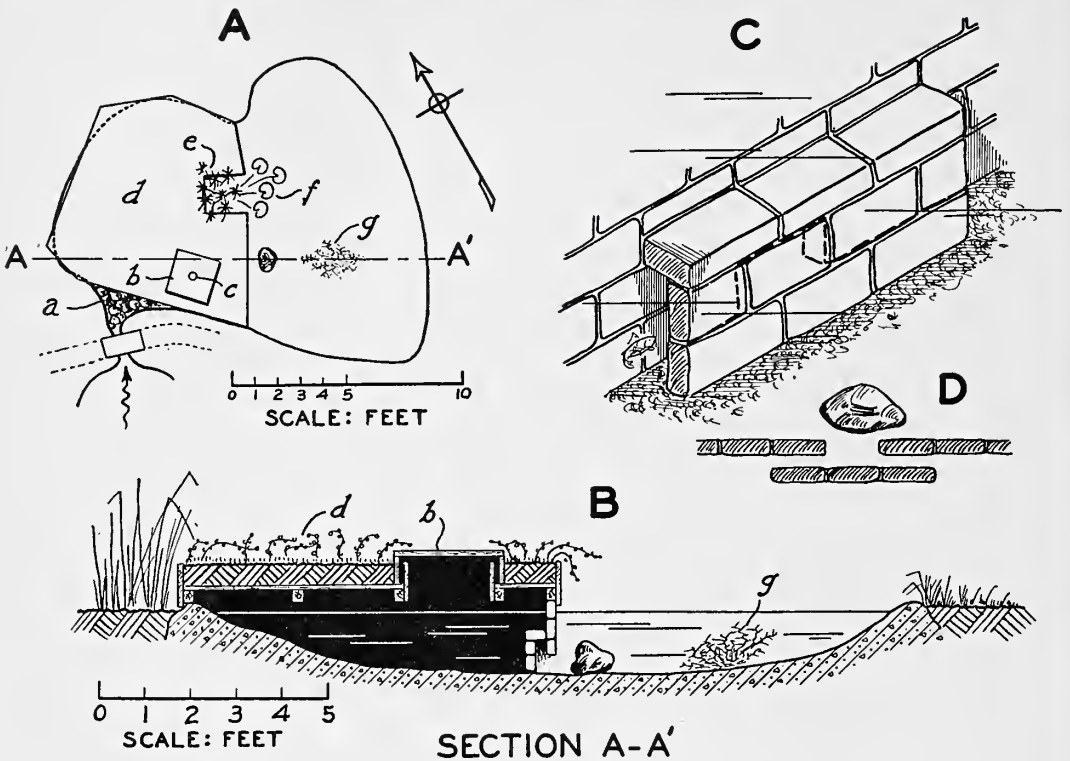
In order to determine how much time was spent in and out of the cave, periods of observation were made on May 26 which cover a total observational time of three hours. The times of entrance and emergence from the cave were calculated. It was found that 83.3+% of the time was spent within the cave and 16.6+%

in the lighted pool. This agrees well with the data of Breder & Gresser (1941) and that given herein in Table I. The present figure, while slightly higher than any of the others, is based on relatively few observations and has been necessarily calculated on a somewhat different basis. Further work of this nature could not be continued when more fish were introduced for a variety of purely practical reasons. Also it was subsequently found that other influences so modified this light avoidance reaction, which were not present in the laboratory work, that additional readings would have been without value. As it developed it was found that these influences could be readily understood and described but did not lend themselves easily to a statistical approach or analysis in this outdoor pool. Usually a few blind fish could be seen but there were long periods when all were in the cave and equally long ones when all were out of the cave. When the normally visioned river fishes were introduced on June 2, they also partook of this variation in habit. In their case, with marked schooling habits, it was clear that the activities of one individual had a sharp bearing on the others. Here, as in aquaria, they would attempt to school with a blind fish wandering by but soon gave up to return to their own apparently more satisfactorily behaving eyed com-



Text-figure 1.

Comparison of behavior between experimental and control specimen (shown in solid lines) together with the data of Breder & Gresser (1941) (shown in dotted lines) in terms of expectancy of random movement.



SECTION A-A'

Text-figure 2.

Construction and details of experimental "cave." A. Plan of pool and cave as constructed. B. Section through pool and cave. C. Light trap as seen from inside cave. D. Plan of light trap. a. Loose stones and gravel to form light trap and block fish exit at point of inflow to pool. b. Trap door to cave. c. Corked hole in trap door for feeding and temperature reading. d. Roof of cave composed of flooring on stringers covered with soil and planted with vines. e. Large *Cyperus* plant. f. *Nymphaea*. g. *Nitella*.

panions. This plus the large areas involved apparently prevented the results disastrous to the blind individuals noted by Breder & Gresser (1941). At least at no time was anything seen that could have been interpreted as an attack on the blind by the normal eyed fishes. At times the addition of water would cause all to rush into the outflowing stream and enter the cave, where presumably they sought the blocked inflow from the other pool.

These effects were variable and at first puzzling but it soon appeared that the causes lie in temperature differentials between the cave and the open pool. For example there was a marked tendency for all the fishes to be out in the open in the daytime and to retreat to the cave at dusk, both eyed and blind alike. During the daytime the open pool would warm under the influence of solar radiation and rise several degrees above the cave temperature while at night it would drop below that of the cave which because of its cover did not lose its temperature nearly so fast. A study of Table II will indicate how these varying seasonal and diurnal temperature changes effected the relationships of the

water temperature in the cave to that in the open pool. The results may be summarized as follows:

1. If the temperatures were identical, or nearly so, the fish would move in and out freely, usually with the majority of blind fish out of sight and the eyed specimens in a compact school in the lighted pool.
2. A difference of as little as 1.5° F. between the cave and the open pool would cause practically all to be in the warmer section, independent of time of day or brightness of light.
3. Water entering from the other pool would have various effects dependent on whether it was warmer than that in the cave or not. If the cave was notably cooler than either pool the water first passing into the lighted portion and cooling it would first prevent the fish from entering the cave and later as the cave warmed from the new water and the open pool cooled they would all enter, stimulated both by flow and temperature.

Many of both types of fish were evidently gravid during the middle of summer but it is doubtful whether any spawning took place as the

TABLE II.

Temperatures and related data.

Date	Hour	Water temperatures °F.				Min.
		Cave	Pool	Max.	Min.	
May 23	9:00 p.m.	—	73	—	—	2 cave fish in pool
24	7:00 p.m.	—	—	70	64	
25	7:00 p.m.	—	—	65	58	
26	10:30 a.m.	62	69	—	—	
	4:00 p.m.	60	67	—	—	
	7:00 p.m.	—	—	69	57	
29	8:00 p.m.	—	—	77	66	
30	3:00 p.m.	66	67	72	62	10 cave fish in pool
31	8:00 p.m.	—	—	74	60	
June 1	4:00 p.m.	63	62	—	—	
	6:00 p.m.	—	—	66	61	
2	8:00 p.m.	65	65	72	61	9 river fish in pool
3	8:00 p.m.	—	—	75	61	
4	6:30 p.m.	—	—	70	61	
July 14	3:00 p.m.	69	73	—	—	
18	8:00 p.m.	—	—	75	67	
20	8:30 p.m.	—	—	78	63	
22	7:45 a.m.	69	67	—	—	
	8:00 p.m.	69	73	78	62	
23	7:45 a.m.	70	69	—	—	
	8:00 p.m.	74.5	77	82	67	
24	7:45 a.m.	73	71	—	—	
	8:00 p.m.	78	76	81	68	
26	8:30 a.m.	75.5	75	—	—	
	8:00 p.m.	75.5	78	82	71	
27	10:30 a.m.	74	76	—	—	
	8:00 p.m.	77	78	82	67	
30	7:30 p.m.	72	72	78	70	
31	6:30 p.m.	72	72	71	70	
Aug. 2	9:30 a.m.	73.5	73.5	77	69	
	7:00 p.m.	74	75	79	75	
3	8:00 p.m.	72.5	73.5	79	66	
16	9:00 a.m.	66	67	83	53	
18	5:00 p.m.	64	66	73	53	
28	2:00 p.m.	65	66	78	58	
Sept. 5	9:00 a.m.	67.5	66	79	53	
8	10:00 a.m.	66	63	70	56	
	1:30 p.m.	65	66.5	—	—	
	4:00 p.m.	67	66	—	—	
13	2:00 p.m.	62	60	—	—	Removed fish, 1 cave, 4 river.
Mean		69.2 +	70.1 —	75.3 +	62.9 +	
			69.1 +	(average of all min. and max.)		
Maximum		78	78	83	75	
Minimum		60	60	65	53	

Note. Columns marked "Max. and Min." read on a minimax thermometer at hour noted and reset for next reading.

temperatures were probably below their spawning threshold. In any event there were no young evident, although either eggs or very young fish may have been eaten by the adults or by aquatic insects if such were actually produced.

The experiment was terminated with the advent of cool weather as it was evident that soon their lower threshold would be passed. As it was, some of the minimum temperatures reached and survived by these fish are rather remarkable, especially when it is borne in mind that the home waters of these fish hover about 80° F. Since the fish were variously in and out of the cave it was impossible to keep a close check on the actual numbers present. When the fish were removed on September 13 it was found that only five remained, one blind and four eyed. Less than two weeks previously many more than this

number were seen when a warm day drew them out of the cave. It is suspected that with the cooling water and a failure of their alertness that they fell prey to frogs, as the most likely predator normally about these pools. No matter what the cause of their destruction, under the conditions of natural enemies, fluctuating temperatures, et cetera, it is clear that a marked differential of survival is present. Reduced to terms of percentage, 10% of the blind individuals survived while 44 + % of the eyed ones were still there when the experiment was terminated. Although it must be admitted that the total numbers are small, those that were recovered were in an excellent state of vigor and are now in aquaria. We have every reason to believe that the difference in numbers has bearing on both the blindness and light color of the cave fish. Incidentally it seemed odd that the frogs did not catch the blind

fish early in the experiment, for although they knew their way around the pool they could not tell where a large frog might be floating and if both were present would sooner or later bungle into the frog's dangling hind legs. At first this unaccustomed accident would cause the frog to give a typical fright reaction but soon the frogs became accustomed to such incidents and on occasion they would turn and act as though to pursue the blind fish. The safety of these fish seemed to reside in the fact that customarily when they do strike into something they ordinarily charge off into another direction at top speed, and then not infrequently seem to be confused and are likely to strike the bottom or something else with which they are fully familiar and take some little time to quiet down again.

DISCUSSION.

Since it has been shown that reactions to temperature gradients override reactions to light in both blind and visual types it may well follow that temperature differentials in a state of nature form an important influence on the entry and further penetration of these caves. There would thus seem to be at least three factors in the behavior of these fish leading to cave entry.

1. Negative phototaxis on the part of blind fish and a tendency for visual types to hide in dark places and peer out.
2. Positive rheotaxis tending to cause these fishes to swim upstream.
3. Positive thermotaxis tending to cause these fishes to move into warmer waters.

The first two requirements of the environment are met by La Cueva Chica and while at the time of our visit the subterranean waters were practically of the same temperatures as surface waters, surely at other seasons the ground waters are warmer than those of surface drainage. During the dry season these ground waters should be cooler than those of the surface if they were not heated from below, a geologic feature of this region with its magnetic layers close to the surface and with an abundance of warm springs.

Although the temperatures encountered in the field were considerably above those obtainable in the pool experiments there is no reason to suppose that the fishes' behavior would be any different in regard to thermal preferences. Incidental to this is the fact shown by Doudoroff (1938) that a variety of marine species will select water warmer than that of their normal habitat, if given the opportunity.

This finding of a temperature gradient reaction helps to account for the presence of fishes as remote from the cave's exit as is evidently possible for them to reach, for presumably there is such a gradient from these cave springs, where they rise from the depths, to the juncture at the river, during part of the year at least, although in the short section of the cave available to human exploration no such gradient was detected.

The cave water temperatures taken in a wide variety of places varied scarcely at all from 80° and this quite erratically. In aquaria, the same fish appeared to be not in the least inconvenienced by temperatures in the low ninety degrees although eggs laid in water of such temperatures failed to develop normally. Temperatures as low as 65° and for short intervals dropping to 53° have been survived. It thus appears that these fish have a rather wide temperature tolerance. Nevertheless, normally eyed river fish, hatched in an unfurnished, rectangular and well lighted aquarium with no opportunity to hide at all, voluntarily entered a simulated cave where their eyes were useless, on the stimulation of slight flow or a slight thermal difference. Blind fish of the fifth generation raised in light and without previous experience behaved the same way. Given fishes with three such items in their normal behavior, all that would seem to be necessary, in addition, to establish the observed condition in La Cueva Chica would be a genetic defect involving the eyes and cave factors of the types described.

The differential in survival under the conditions of the experiment may mean but little in terms of the Mexican caves but since the experimental temperatures drew the blind fish out of the cave nearly daily it is tempting to imagine that, had it been possible to reverse conditions at will, a much larger number of blind individuals would have survived.

SUMMARY.

1. Light sensitivity in *Anoptichthys* is lodged in the apparently functionless remnant eye capsule, which may be demonstrated by its removal.
2. Reactions to temperature overrides the influence of light in both the eyed and blind forms and rheotaxis interferes to a lesser extent.
3. Eyed individuals apparently do not attempt to destroy blind ones except under conditions of close confinement.
4. Normal river fish, which never before had an opportunity, entered a simulated cave on temperature differentials of less than 1.5° F. as well as on a slight flow emerging from the darkness.
5. Survival in an outdoor pool divided about equally between light and dark was in favor of the eyed forms slightly better than 4 to 1.
6. Three factors have been experimentally demonstrated as parts of the normal behavior pattern of both eyed and eyeless fishes, which would tend to make them enter caves similar to the one in which found, namely: negative phototaxis, positive rheotaxis and positive thermotaxis.

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EXPLANATION OF THE PLATE.

- Fig. 1. The pool and "cave" as it appeared with the construction work finished but before the placement of soil and planting.
- Fig. 2. The pool and "cave" as it appeared shortly after planting. Later the vegetation became considerably more lush, hiding all of the woodwork.



FIG. 1.

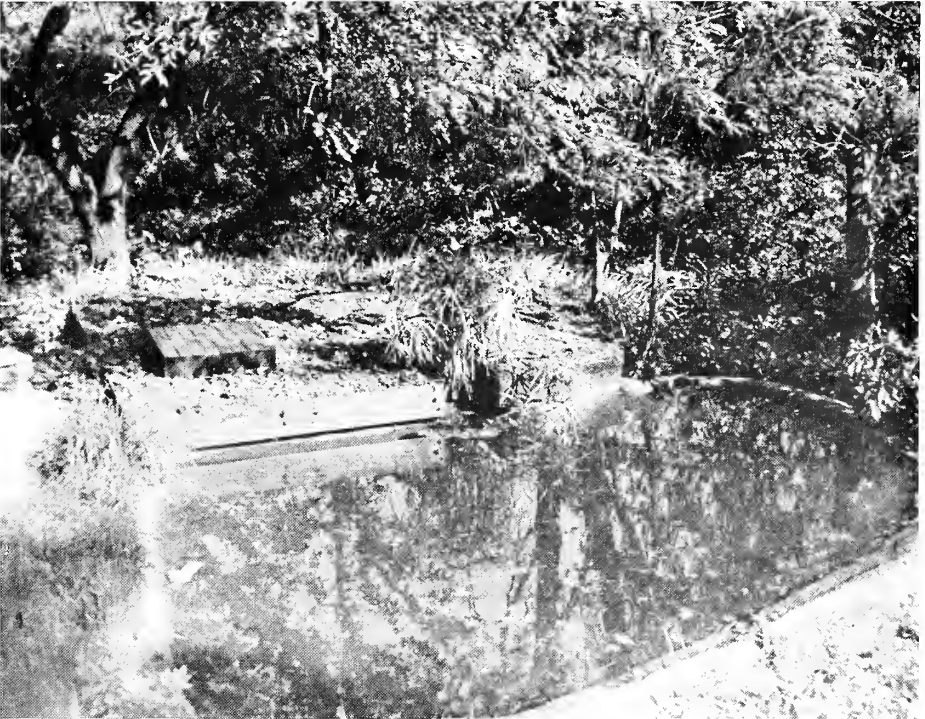


FIG. 2.

FURTHER STUDIES ON THE LIGHT SENSITIVITY AND BEHAVIOR
OF THE MEXICAN BLIND CHARACIN.

29.

**Eastern Pacific Expeditions of the New York
Zoological Society. XXIX.**

**On the Growth and Ecology of Brachyuran Crabs of the Genus
Ocypode.¹**

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(Plates I-II. Text-figures 1-7.)

[This is the twenty-ninth of a series of papers dealing with the collections of the Eastern Pacific Expeditions of the New York Zoological Society made under the direction of William Beebe. The present paper is concerned with specimens taken on the Eastern Pacific *Zaca* Expedition (1937-1938). For data on localities and dates of this expedition, refer to *Zoologica*, Vol. XXIII, No. 14, pp. 287-298. Also included in the present paper are results of observations made by the author on the Pacific coast of Panama during January, 1941.]

The references given under each of the two species discussed include the type description, Rathbun's monograph (1917), and occurrence records which have appeared since the latter date. The collection is deposited in the laboratory of the Department of Tropical Research, New York Zoological Society.

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I. INTRODUCTION.

The present paper is the third of a series dealing with the brachyuran crabs of the Eastern Pacific *Zaca* Expedition. My sincere thanks go to Mr. Templeton Crocker for the opportunity of making these collections and of studying the crabs in the field, to Dr. William Beebe for his unflinching helpfulness and for leave of absence making possible a special trip to Panama, and to Miss Janet Wilson for her excellent drawings.

II. SUMMARY OF IMPORTANT POINTS.

1. Young crab stages of *Ocypode gaudichaudii* and *O. occidentalis* differ from adults chiefly in the flatter, more narrow carapace, longer legs, larger eyes, more oblique orbits, smaller chelipeds and different coloration. In *gaudichaudii* the ocular stiles and truncate chelae begin to develop when the crab is less than half grown, the carapace being around 7 mm. in length when the first trace of stiles appears, and 10 mm. when the chelae tips begin to show change in form. In adult males the stile is only slightly longer than in females; this difference is not apparent in young crabs.

2. Adult *gaudichaudii* apparently alone of all the genus feeds habitually on microscopic organic matter in the sand, just as do crabs of the related genus *Uca*. In *gaudichaudii*, however, the technique differs: first, a raking motion of the truncate chelae is substituted for the pinching of sand by the pointed, spooned chelae in *Uca*; second, the specialized endites of the first maxillipeds form sand pellets which drop of their own weight, instead of being wiped off as in *Uca*. Young *gaudichaudii* habitually, and adults rarely, prey on small crustaceans, insects and worms, and sometimes add wood and seaweed to

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Text-figure 1.

Shore collecting stations of the Eastern Pacific Expeditions of the New York Zoological Society.

their diet. *O. occidentalis* is a predator and scavenger.

3. *O. gaudichaudii* is diurnal, *occidentalis* nocturnal except when very young.

4. In contrast to the racing dodging, burrowing adults, the young of *gaudichaudii* run only a short distance when pursued, then flatten themselves in the sand, where protective coloration aids them in escaping observation.

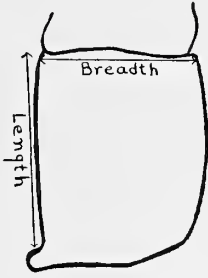
5. Also included in the present paper are descriptions of color in life, stridulation, habitat, burrows and daily schedule, with special emphasis on *gaudichaudii*. Abdominal appendages of the three American species, *gaudichaudii*, *occidentalis* and *albicans*, are illustrated.

III. KEY TO IMMATURE *Ocypode* FROM THE EASTERN PACIFIC.

O. occidentalis and *O. gaudichaudii*, although so distinct in the adult, are superficially indistinguishable up to a length of about 7 mm., when the ocular stiles and truncate chelae of the latter species begin to develop. However, they may be distinguished when alive by color differences, and when preserved by the proportions of the buccal frame, as shown from the following key. The smallest specimens studied were about 4 mm. in length.

The length of the ischium of the third maxilliped is measured along its external margin in a straight line, as far as but not including the

basal process; the breadth of the ischium is measured across the distal margin. The accompanying diagram illustrates these points.



- 1a. Living crab with a spot of brilliant scarlet on middle of posterior gastric region, and others on one or more of the meri of the last three pairs of ambulatories. Breadth of ischium of third maxilliped 58 to 69 per cent of its length. *occidentalis*, p. 308
- 1b. Living crab without scarlet spots. Breadth of ischium of third maxilliped 77 to 85 per cent of its length. *gaudichaudii*, p. 209

IV. CRABS OF THE GENUS *Ocypode* TAKEN BY THE EASTERN PACIFIC *Zaca* EXPEDITION.

Ocypode gaudichaudii Milne Edwards & Lucas.

Text-figs. 2; 4 A, B, C, D; 5 B, D, F, H; 6 B, D; 7 E, F; Pl. I, Fig. 1; Pl. II, Figs. 3, 4.

References: *Ocypode gaudichaudii* Milne Edwards & Lucas, 1843, p. 26; 1847, pl. 11, figs. 4-4b. *Ocypode gaudichaudii*, Rathbun, 1917, p. 373; pl. 129, fig. 1; pl. 130, fig. 1; Boone, 1927, p. 267, fig. 96A; 1929, pp. 562, 580; Pesta, 1931, p. 174; Sivertsen, 1934, p. 19; Crane, 1940, p. 67; text-figs. 1-8.

Range: Gulf of Fonseca, El Salvador, to Chile; Galápagos Islands.

Local Distribution: Found on more or less protected beaches and on the shores of lagoons. In one locality (Bahia Honda, Panama), there were more than 3,000 crabs on a beach measuring about 175 × 400 feet. Very rarely found on the same beach with *O. occidentalis*, and then usually one or the other species occurs in the young stages only, so that its presence is doubtless accidental.

Size: The 55 specimens in the present collection measure between 4.8 and 29 mm. in length of carapace. One of Sivertsen's (1934) males from Galápagos was 36 mm. long, and a female 34 mm.

Sexual Characters: Except for the probably larger maximum size and slightly longer ocular stiles of the male, there are no apparent secondary sexual characters. The form of the abdominal appendage in this genus, as in *Uca*, varies among the species, so that it should prove a valuable taxonomic character in the determination of dubious forms. Plate II, Figs. 4, 5 and 6 illustrate the appendages of the three American species.

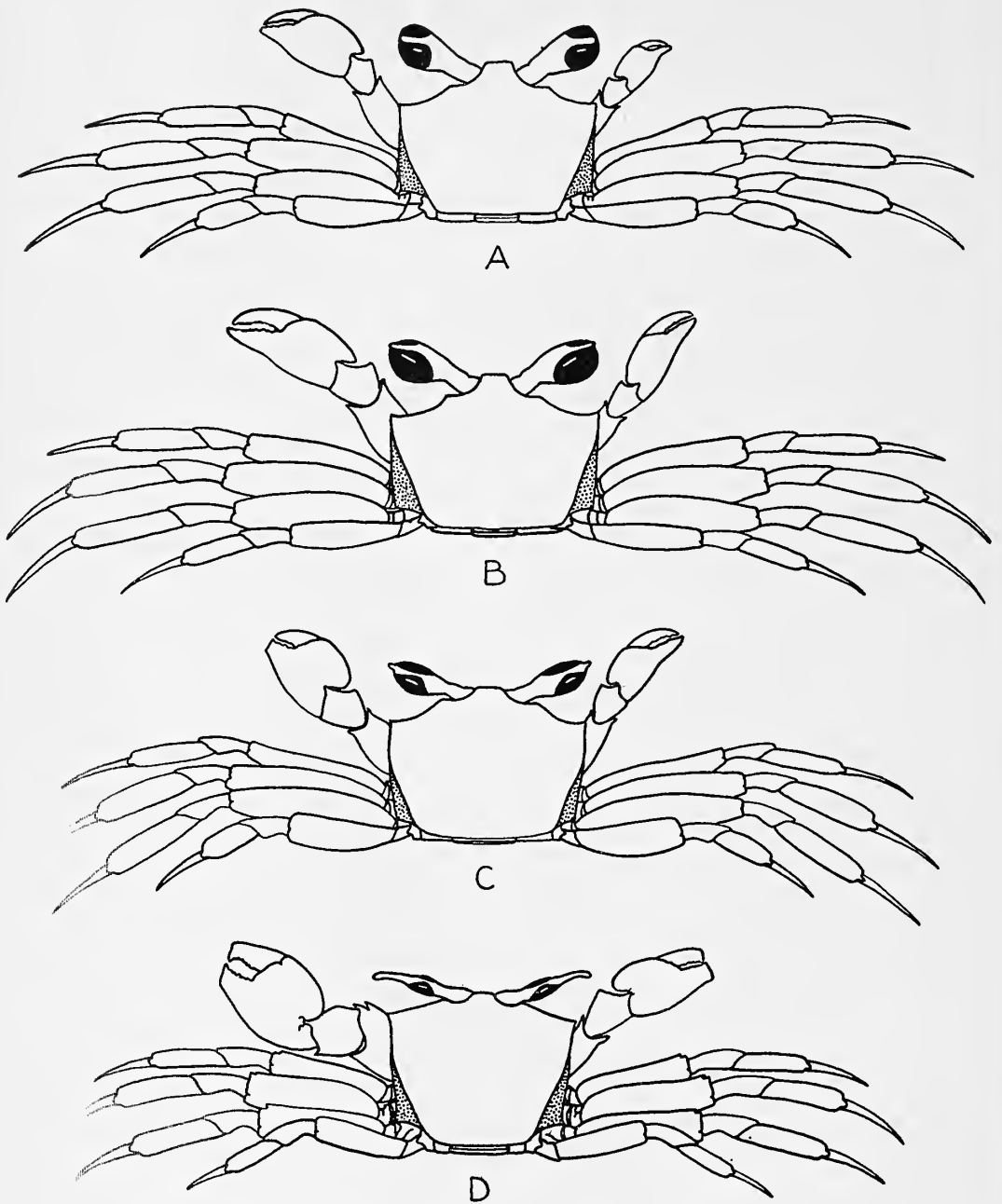
Color: This species ranges in general color from brilliant coral red to dark brown, marbled or mottled with brown, yellow and yellow-green. The exceedingly variable color is affected by a number of factors, including the color of the sand

upon which they live and the sex and size of the individual. No precise observations have yet been made on the influence of light and temperature on the one hand, or of physical and emotional states on the other, but these will undoubtedly prove to be of great importance, and the crab found to be capable of considerable individual variation. The only exact notes taken on the latter subject concerned an ovigerous female: the sides of the carapace were gray-violet when the crab was captured on a dark, stormy day after a long chase over light sand; they changed to moderately bright coral red after two days in a box kept partly in sunshine, its bottom being covered with the same light sand. There was no color change at night. Compare especially the observations of Cowles (1908) on color change in *O. albicans*, Abramowitz & Abramowitz (1940) and Brown (1940) on the effect of eyestalk removal in *Uca*, and Crane (1941) on color change in courting *Uca*. Similar experiments and observations made upon *O. gaudichaudii* should yield interesting results.

In regard to the effect of the environment, it was obvious that crabs on light sand were brightest, with a great deal of orange, carnelian and coral pink, while those on dark, volcanic sand were darkest, with these brilliant colors replaced by browns, rusty oranges and pale pinks. In any group the adult males were brightest, the females paler, the young palest. In specimens less than about 15 mm. long, the parts that were yellow in adults were white, those that were coral or carnelian red were lavender or violet; especially noticeable in the young was a band of violet across the posterior part of the carapace.

Colors of adult males have been noted in detail as follows: ground color of carapace ranging from bright coral or carnelian red in colonies living on the palest yellow sand, through coral pink and rusty orange, to dark brown in colonies on dark slate-colored sand; carapace with mottlings or marblings ranging from pale lemon yellow or chartreuse with dark brown to ochre or chartreuse with cream and white; sides of carapace brilliant clear orange to scarlet orange, sometimes mottled with pink. Eye sockets brilliant orange to dark brown; stalks coral red to pearl gray; eyes pearl gray; stiles scarlet orange to yellow-brown. Merus and carpus of chelipeds orange or orange-brown above with brown mottlings, buffy yellow below and on inner surface; upper third of manus bright coral pink or orange to dark brown; lower two-thirds pinkish-white to lemon yellow; chelae coral pink, orange or lemon yellow. Posterior (dorsal) surface of ambulatories usually like carapace, but dactyls are buff when crab lives on light sand, olive green when on dark sand; anterior (ventral) surface of ambulatories usually pale. Sternum and abdomen bright coral pink, sometimes mottled carnelian red, yellow and white, sometimes fading into white posteriorly.

Early Crab Stages: Several excellent studies on the growth of *Ocypode* have already been pub-



Text-figure 2.

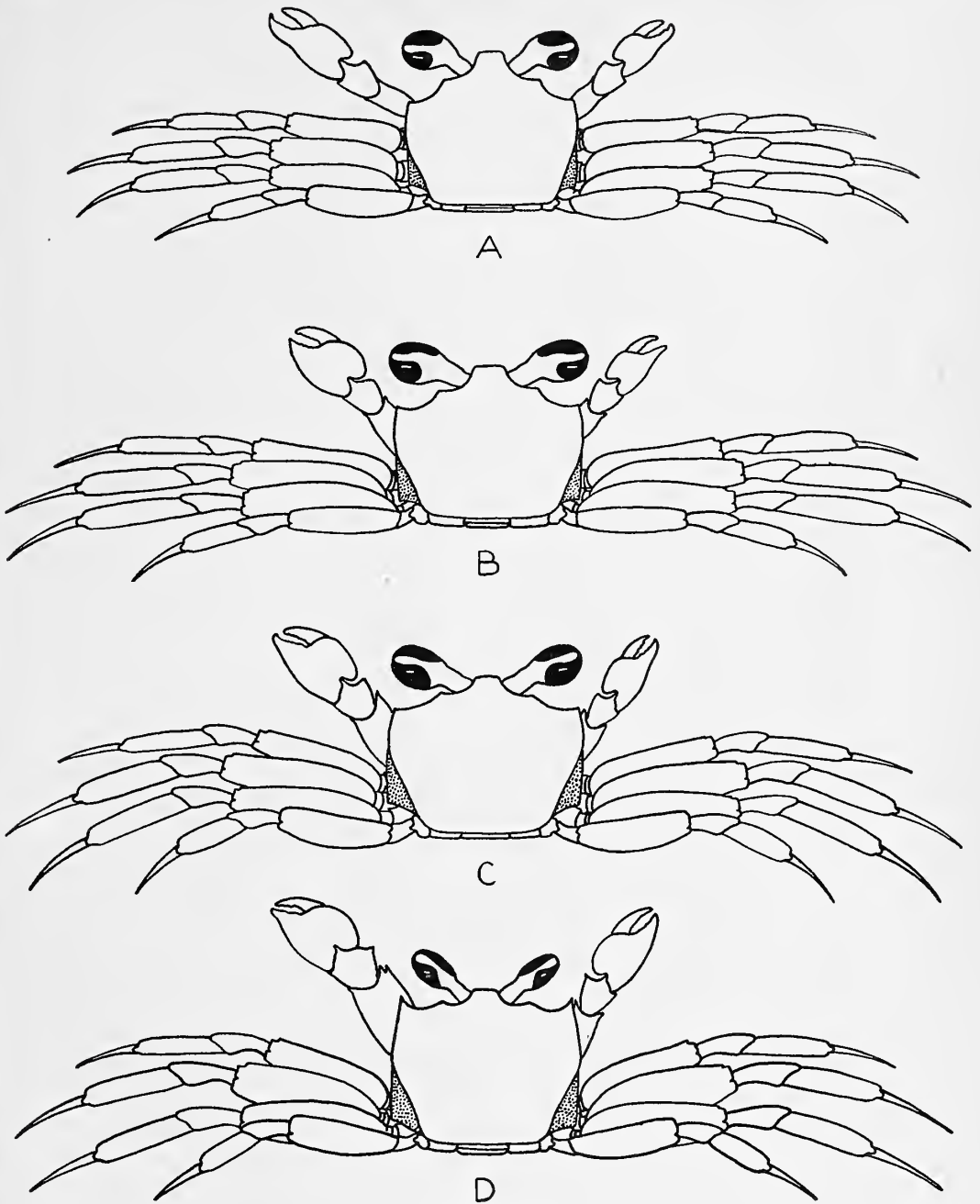
Ocypode gaudichaudii. Growth stages. Carapace lengths: A, 4.8 mm.; B, 7.2 mm.; C, 10 mm.; D, 29 mm.

lished, notably those of Cott (1929), Huxley (1931) and Sandon (1937). It seems worthwhile, however, to summarize and illustrate the changes occurring during growth in *gaudichaudii*, especially since this species is more specialized than others studied (*ceratophthalma* and *aegyptica*).

The changes in *gaudichaudii* were studied from

a series of 64 specimens ranging in length from 4.8 to 29 mm., the carapace being measured in the median line. The outstanding growth characters of the young are as follows, all of the observations being of course relative to the size of the crab.

1. The carapace is broader than in the adult,



Text-figure 3.

Ocypode occidentalis. Growth stages. Carapace lengths: A, 4.2 mm.; B, 6.9 mm.; C, 10 mm.; D, 25 mm.

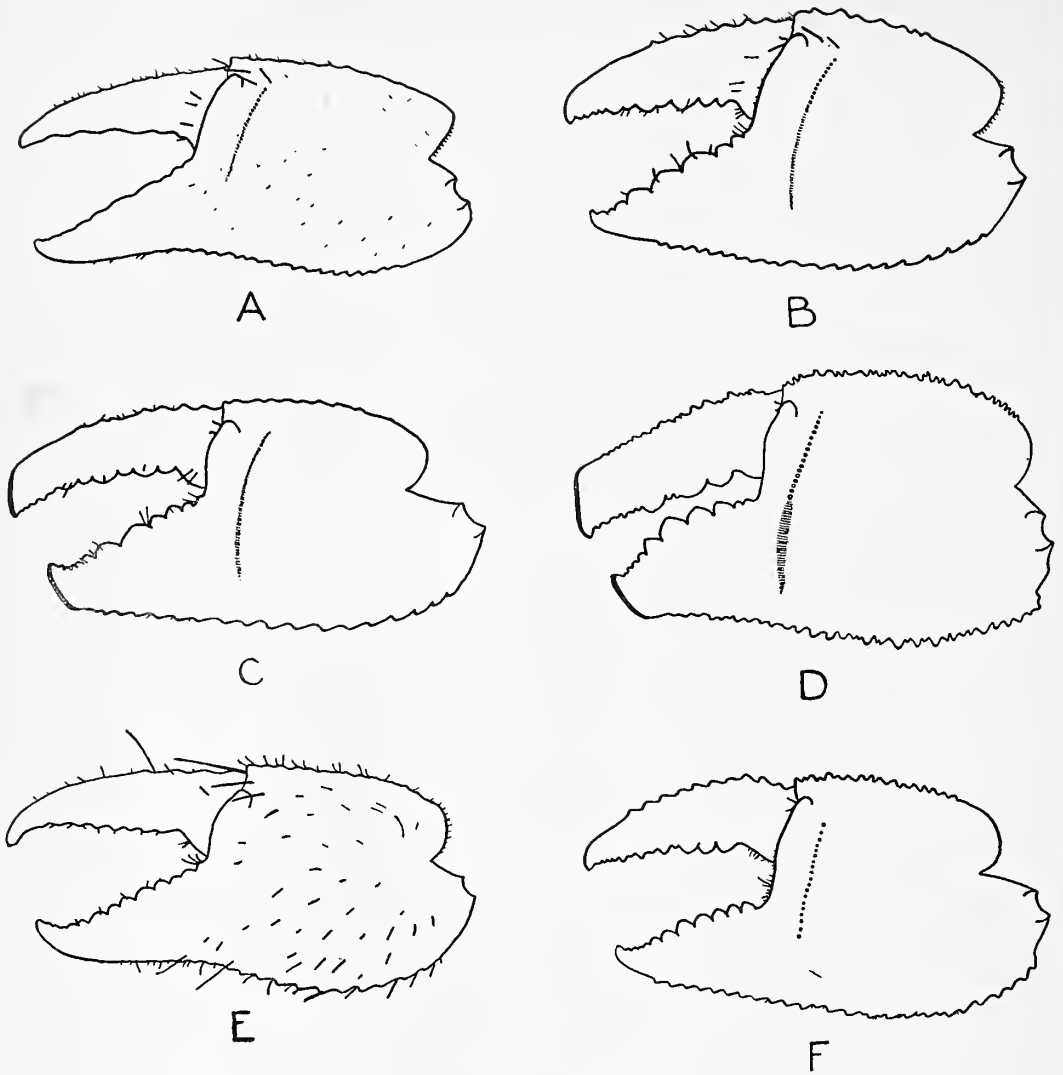
breadth being greatest when the crab is about 7 mm. long.

2. The carapace is less deep.

3. The orbits are more oblique.

4. The eyes are enormous, being broader and thicker as well as longer.

5. The eyestalks are longer and thicker, but there is no trace of stiles until the crab reaches a length of about 7 mm. In their early stages, the stiles are equipped distally with a few hairs, as in adults of certain other *Ocypode*. The stiles will be further discussed below.



Text-figure 4.

Major chelae of *Ocypode*. A to D, incl., *gaudichaudii*: A, female, carapace length 4.8 mm.; B, female, carapace length 7.2 mm.; C, male, carapace length 10 mm.; D, male, carapace length 29 mm. E, F, *occidentalis*: E, female, carapace length 4.2 mm.; F, male, carapace length 25 mm.

6. All the joints of the chelipeds are more slender, the width of the manus being only three-fourths that of the grown crab in a specimen 4.8 mm. long.

7. The chelae show the first signs of truncation when the crab reaches a length of about 10 mm.

8. A stridulating ridge is present even in the smallest (4.8 mm.) crabs, but is composed only of minute, homogeneous granules, instead of having parallel, elevated lines in its upper half. In these smallest examples the inside of the palm is slightly hairy.

9. The ambulatories are relatively longest when the crab is about 7 mm. in length.

10. The colors of the young have already been noted (p. 299).

11. The crabs appear, anatomically, to reach maturity at a length of around 22 to 24 mm.; this point cannot, however, be settled until more is known of their breeding habits. The only ovigerous female taken measured 27.5 mm. in length.

Stiles: A number of writers (for example, Ortmann, 1894, p. 768, Lanchester, 1900, p. 759, and Gordon, 1934, p. 9) have mentioned the fact that in other species of *Ocypode* furnished with ocular stiles the latter are absent in the young and reach their maximum development in large

males. In *O. ceratophthalma*, stiles do not begin to develop much before a length of 20 mm. is reached (Lanchester, *ibid.*), in contrast to *gaudichaudii*, in which, as has been said, stiles are first visible at a length of about 7 mm. In *gaudichaudii*, too, the sexual difference in stile length is relatively slight, and is not apparent at all until the crab measures about 20 mm. Indeed, in smaller crabs, the stiles on the average are even slightly shorter in males than in females. In both sexes, the stile grows more rapidly after the crab has reached a length of about 20 mm. The following table is based on a series of 31 males and 23 females.

Length of carapace in mm.	Length of stile in mm.	
	Males	Females
4.8 to 6.6	Absent	Absent
7 to 14	0.2 to 1.2	0.1 to 1.0
15 to 19	1.1 to 1.9	1.3 to 2.4
20 to 24	2.4 to 4.3	2.4 to 3.5
25 to 29	4.6 to 7.5	3.2 to 5.5

Largest male, 29 mm. long, stile length 7.5 mm.

Largest female, 27.5 mm. long, stile length 5.5 mm.

Dembowski's detailed description (1913) of the glandular organs of the ocular stile and stalk of *ceratophthalma* has apparently not been superseded, while Parenzan (1931) ascribed to the stiles of the same species a tactile and protective function in addition to their glandiferous capacity. It will be interesting to study in detail the functions of both stiles and glands, and to determine whether the latter control chromatophore expansion, as do the sinus glands in the eye-stalks of *Uca* and other crustaceans (see for example Abramowitz & Abramowitz, 1940; Brown, 1939; and Kleinholz & Bourquin, 1941).

Food, Feeding and Mouthparts: Unlike other members of the genus, which are confirmed predators and scavengers in the usual sense of the word, *gaudichaudii*, except when very young, feeds almost entirely on microscopic organic matter washed onto the sand by the tide, exactly as does *Uca*. As in the latter genus, the minute particles of animal and vegetable matter are gathered by sifting pinches of sand through the mouthparts and dropping the remaining sand in small pellets from the posterior part of the buccal region. In feeding, alternate claws are used, at the rate of four scoops to the second; pellets emerge at two to the second. Rejected pellets of large crabs measure on the average one-quarter to three-eighths of an inch in length and are broadly oval.

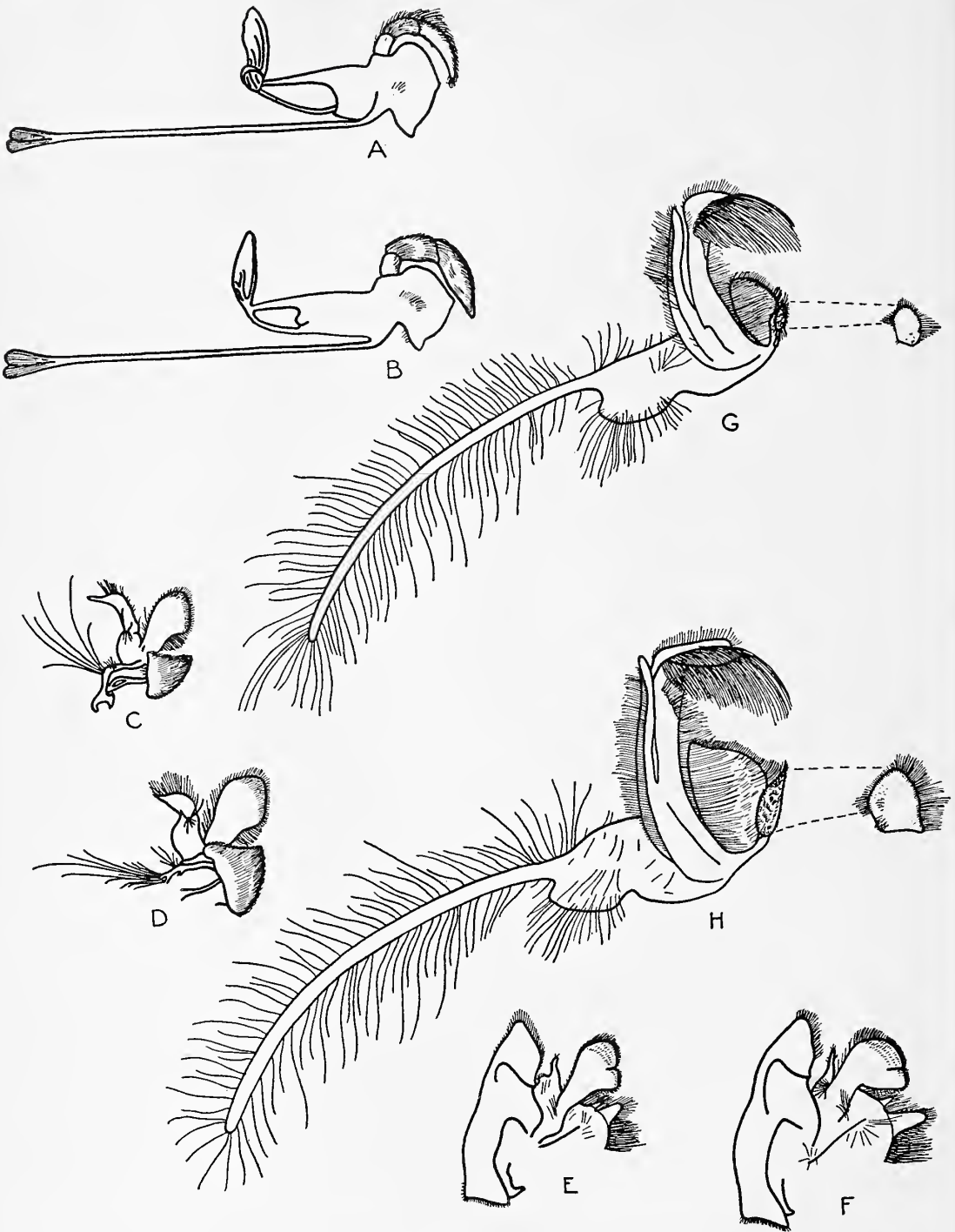
The details of the method by which the food is gathered, although analogous to the procedure in *Uca*, are in *O. gaudichaudii* unique. In *Uca* the minor chelae are spooned, and literally pinch up clawsful of sand, the dactyl being widely extended before every pinch. In *O. gaudichaudii*, the sand is not picked up between the chelae, but instead the latter are held almost closed, and used simply as broad-toothed rakes, scraping backward, inward and upward. The inner surfaces of both dactyl and pollex are

slightly concave, and this characteristic, combined with their truncate tips, must make them almost or quite as efficient sand-gatherers as the entirely different chelae of *Uca*. Each scoop of sand, as in *Uca*, is swiftly lifted to the anterior end of the buccal cavity, where it is swept from the chelae by the palps of the third maxillipeds. No way has yet been found of watching exactly how the organic matter is separated inside the mouth, although as in similar observations on *Uca* the parts can be seen to be in rapid motion.

Whatever the details of manipulation in *gaudichaudii*, it is apparent that the sand about to be rejected is formed into a pellet in the middle of the lowest (most posterior) part of the buccal cavity, between the enlarged endites of the first maxillipeds. The pellet is not wiped off by the chelae, as in *Uca*, nor does the sand simply accumulate outside haphazardly and drop by means of gravity; instead, it appears to be carefully moulded into a pellet, by the up-and-down motion of the endites, and dropped. Since damp sand lacks much of the stickiness of mud, such a procedure is practicable in this crab, whereas it would be impossible in most *Uca*, which are largely mud-feeders (cf. Crane, 1941). The technique of separation is not perfect, since small amounts of sand are usually found mixed with the organic matter in the alimentary canal.

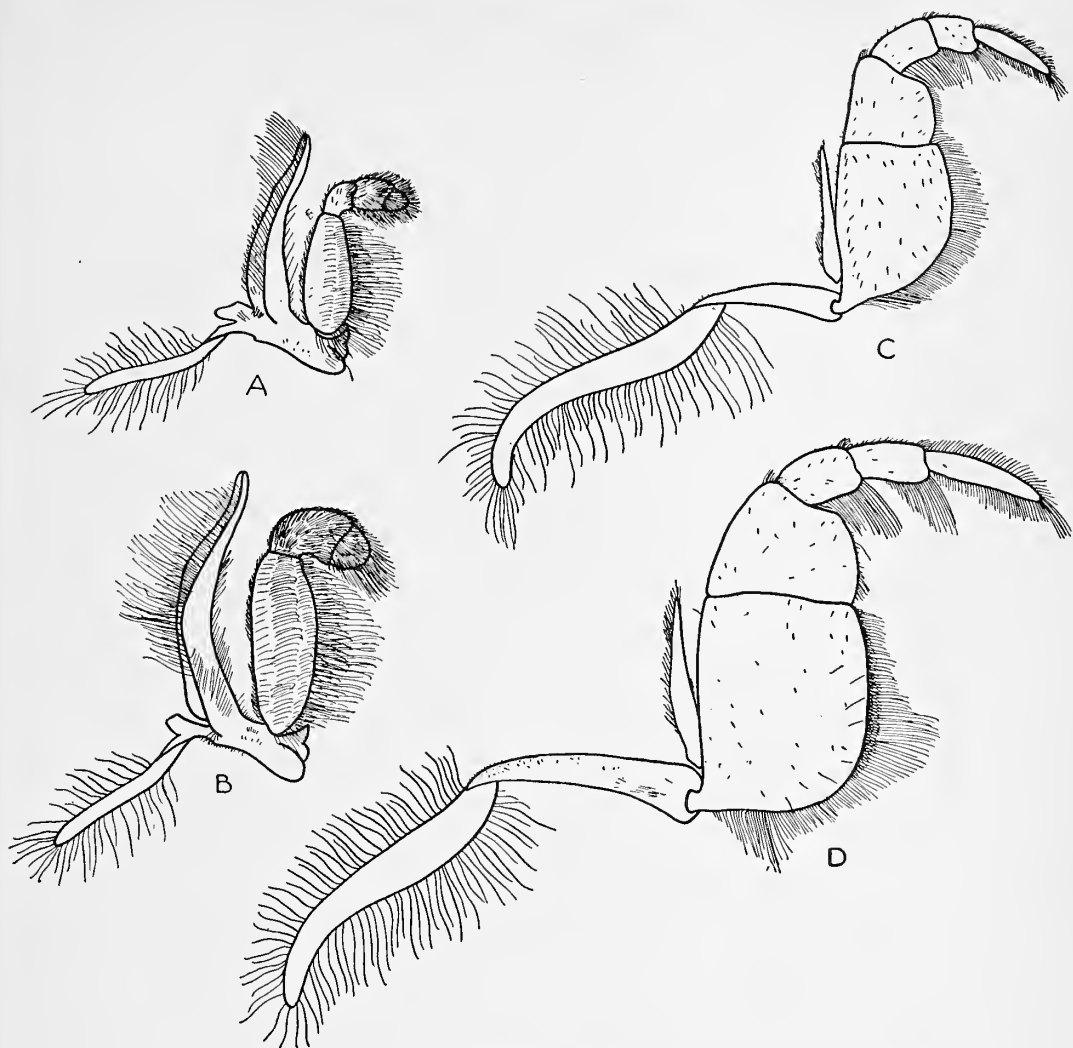
A comparison of the mouthparts of *gaudichaudii* with those of *occidentalis* is enlightening. The latter in feeding habits is a typical *Ocypode*, the west coast analogue of *albicans*, and feeds on the usual assortment of seaweed, carrion, amphipods, insects, etc. I have never seen it put sand into its mouth, and have rarely found grains in its stomach.

In *gaudichaudii*, the entire mouth field is much larger than in *occidentalis*, ranging from 25 to 30 per cent. more in both length and width, and with the parts correspondingly larger, a condition which is apparently useful in manipulating large quantities of sand. In *gaudichaudii*, too, the hairs on the mouthparts are much longer and thicker, although not as long as in mud-living *Uca*'s, where even more straining work is necessary than in sand-living *Ocypode*. Specifically, the hairs on the inner margins of the third maxillipeds are up to more than three times as long, and those on the second maxilliped one and a half times to twice as long. The maxillae are also larger and tougher and the mandibles slightly longer. There are no pectinated spoon-tipped hairs, so characteristic of most fiddler crabs, on the second maxilliped of either species of *Ocypode*; in both, however, there is a row of short, thickened hairs on the inner (dorsal) side of the merus and a cluster of similarly thickened and slightly concave hairs among the normal ones on the tip of the palp; these stout hairs are slightly longer and more numerous in *gaudichaudii* than in *occidentalis*. The anterior margin of the sternum is broader in *gaudichaudii*, squared off and slightly concave, perhaps for better retention of the sand during manipulation, while



Text-figure 5.

Mouthparts of *Ocypode*. A, mandible, *occidentalis*; B, same, *gaudichaudii*; C, first maxilla, *occidentalis*; D, same, *gaudichaudii*; E, second maxilla, *occidentalis*; F, same, *gaudichaudii*; G, first maxilliped, *occidentalis*; H, same, *gaudichaudii*. All $\times 4.1$, from ♂'s 25 mm. long.



Text-figure 6.

Mouthparts of *Ocypode*. A, second maxilliped, *occidentalis*; B, same, *gaudichaudii*; C, third maxilliped, *occidentalis*; D, same, *gaudichaudii*. All $\times 4.1$, from σ 's 25 mm. long.

in *occidentalis* this area is narrower, sloping and convex.

The most interesting of the differences, however, lies in the development of the proximal endites (basipodites) of the first maxillipeds. In *Ocypode* as in *Uca* there is considerable space between the anterior tip of the sternum, which extends upward between the maxillipeds, and the mandibles. In *gaudichaudii*, however, there is twice as much as in *occidentalis*, in which the extra space is negligible. In *gaudichaudii* this extra space is occupied chiefly by the proximal endites of the first maxillipeds—which, instead of lying almost useless on each side of the sternal projection, with their flat sides turned backward against the sternum (as in grapsids, portunids, etc.), are in *gaudichaudii* and *Uca* enlarged, thickened, and their flat surfaces closely opposed

to each other, exactly like a pair of butter-ball paddles. The distal endites (coxopodites) and the maxillae, in normal position, thus support and strengthen them laterally, instead of being anterior to them. In *occidentalis* the general form and position of the proximal endites are almost the same, but they are so small and weak, and there is so little space for them that they obviously could not function as paddles.

An examination of a series of alimentary tracts combined with observation in the field, showed first, that feeding habits changed with growth and, second, that large crabs occasionally varied their planktonic diet with other items. Twenty-one stomachs and intestines were examined, from crabs measuring between 5 and 29 mm. in length, taken in eight different localities. This series divided itself naturally into two parts,

one including crabs less than 9 mm. in length, and the other of those longer. The seven alimentary canals comprising the first group contained no trace of sand, and the contents consisted entirely of amphipods and tiny insects, including beetles, in an easily recognizable state. Obviously at this stage, in which the chelae have not become truncate, the crabs are chiefly predators—just as they were in the megalopal stage—and, doubtless, scavengers as well. Similarly, their food is identical with that of other *Ocypode* from the young of which, physically, they are scarcely to be distinguished.

After a length of 9 or 10 mm. has been attained, however, the crabs commence feeding almost entirely by means of sifting plankton from the sand. Correlated with this is a concomitant development of the truncate chelae. As was to be expected, the stomach contents of this second group, numbering 14 crabs, consisted of particles of organic detritus, including diatoms and minute algae. Ten stomachs included more or less sand in addition. In only four was non-planktonic matter found, and in these sand was present in the intestine, showing that the unusual food was not habitual: the stomachs of two adults from the same locality held isopods and bits of wood; another had worm spicules and pieces of seaweed; and a fourth held a small crab, probably *Sesarma*. These must be regarded as exceptional; several times I have seen large colonies of *gaudichaudii* scooping up the sand, while a dead fish or bird lay untouched in their midst, although hermit crabs busily feeding on the carcass attested its worth as food to true scavengers.

I have never seen a member of this species behave as reported to Miss Rathbun (1917, p. 374) by Tristan, although I have baited them with a number of objects, edible and inedible, including both animal matter and seaweed: "If anything falls near them," wrote Tristan, "they jump at it with extraordinary rapidity, as a spider in its web, and try to secure it with their claws so as to carry it off quickly to their holes." Similarly, I have never found material of any kind in their holes.

The only mention I find of other *Ocypode* feeding in the manner of *gaudichaudii* is that of Takahasi (1935), who reports that the young of *ceratophthalma* and *cordimana* feed on plankton and make "sand-balls," along with *Uca*, *Scopimera*, *Ilyoplax* and *Mictyris*. It is interesting that the young of *gaudichaudii* are, in contrast, predators.

Burrows: The burrows are of three main types, and I have not been able to discover that each type is the work of a certain size or sex, or dug in a given sort of locality. The most usual form made by adults seems to be a burrow which goes 6 to 12 inches straight down, then turns at a right angle or more and continues for an almost equal distance. Other individuals, however, dig straight down for six inches, and then continue in a slow spiral. Still others dig a simple, oblique

burrow about nine inches long, ending about six inches underground. To discover which, if any, is the normal type, plaster casts must be taken in a number of localities.

The method of digging agrees in general with the method used by other *Ocypode*, the sand brought up being carried by the first and second ambulatories on the side of the minor cheliped (the side which usually enters the hole first and leaves last). The minor cheliped is laid flat against the load of sand, bearing no weight, but holding it in place. Small loads may be taken two or three feet from the hole and flicked six inches still farther, being flung sideways and forward through the legs and under the cheliped of the other side. Large loads, however, which in large crabs are the usual kind, are simply dumped close to the hole.

In Panama City I noticed a habit which had not been apparent in crabs farther north. When the load has been released near the hole, the crabs deliberately stamp the sand flat with the outer sides of the palm of the chelipeds rapping alternately and quickly against the ground. Simultaneously similar motions are made by the dactyls of the first two pairs of ambulatories, which, instead of bearing the weight of the crab on their tips in the usual fashion, are turned inward, so that the weight rests on the dactyls' entire length, and more pounding surface is given. By just a few of the patting motions the heap of sand becomes almost indistinguishable from its surroundings; on the way back to the hole after an absence the crab usually continues the process, apparently to take care of any stray slippings. Also, they frequently stamp in the immediate vicinity of the hole even when they have not brought up a load.

The procedure was exactly similar to that observed in male *Uca* in preparing a smooth display ground, free from pellets and digging lumps alike, in front of its burrow. All the instances were seen on rather dry sand in January. No evidence of courting activity was seen, although it may be that this action is connected with it. It was not seen in equally detailed observation of the species at Bahia Honda, in northern Panama, in March. It may, of course, be connected only with the type of sand, but it is worth noting that it may prove to be a definite part of courtship. Among these stamping crabs a number of rudimentary fights were seen; chelae were never locked as in *Uca*, but were used only in very brief sparring matches.

In one instance, a large crab, the sex of which was not determined, stamped down a fresh load carefully, then darted eighteen inches away to the newly started hole of a smaller crab. The latter had brought up three or four loads and dumped them in as many different places, without stamping them down at all. The first crab stamped down one of the second crab's loads, then chased the animal several feet, watched it keep on running, then returned to the newly started hole and deliberately kicked sand into it

until it was almost indistinguishable from the surrounding beach. The aggressor then returned to its own hole and resumed repair work.

Defense: Crabs of this species employ four distinct types of defense mechanism, according to their size. The smallest noticed, measuring less than 8 mm. in length, are perfectly matched to the sand in color, being finely and evenly marbled with buff and black on carapace and legs. They take every advantage of the similarity in color, since they run only a few feet, or dodge a few inches, when pursued, then flatten themselves and remain motionless on the open sand. These smallest crabs were not seen to escape down holes, even when they were at hand, and apparently had none of their own; the smallest crabs found digging burrows measured between 7 and 8 mm. in length.

If a moderate-sized crab—that is, one too small to have any orange developed dorsally—is dug up and, its hole having been destroyed, allowed to escape, it will, if pursued with moderate force, try to take refuge in a footprint or any other kind of depression in the sand, where it flattens itself and blends in color exceedingly well. However, if still pursued, it will descend any available hole.

Large crabs when pursued never depend on flattening in a depression to escape notice, which would, of course, be impossible thanks to their usually striking color. Instead, they run swiftly, in typical *Ocypode* fashion, to their own hole if possible, or, if not, to that of any neighbor; if this is impossible they dodge and double on the open sand, or seek the shelter of nearby rocks. None of this species, of any size, was seen to take to the water except for a single ovigerous female, which was apparently aerating her eggs.

Large crabs at bay employ the fourth means of defense, which, of course, is the assumption of a threatening attitude, with the nippers upraised and open, as the crab makes every attempt to pinch the attacker.

Stridulation: Alcock's (1892, p. 336) and Anderson's (1894, p. 138) observations on the use of stridulation apply equally well to this species. Whatever its other uses, if any, it certainly is a means of warning trespassers that a burrow is occupied. More than a dozen crabs of both sexes were dropped into the holes of as many others. In each case, when the ear was bent over the hole, distinct twittering squeaks were heard, especially at first. However, if I remained in position, apparently giving evidence of my presence through the shading of the hole, the two crabs always seemed to come to some sort of compromise in regard to sanctuary, the squeaking ceased, and the trespasser remained down the strange hole indefinitely. Naturally, strange large males caused the most commotion. The usual result, as found by subsequent digging, is for the newcomer hastily to dig itself a little niche in the side of the tunnel, the displaced sand forming a loose plug in the mouth. The scrape of the bodies against each other and the

digging sounds can be heard, quite distinct from the stridulation. Although the latter may be imitated artificially with a crab held in the hand, it is higher pitched when performed naturally in a burrow. Presumably only the rightful owner stridulates, but this point has not been checked, as it could perhaps be in a glass-sided terrarium. If the observer retires promptly to a distance of about twelve feet, the trespasser will emerge within two minutes, and pause at the mouth for several minutes more until certain that the danger is past.

Miss Rathbun (1917, p. 374) quoted a note from Tristan regarding this species as follows: ". . . at low tide the crabs begin to come out sideways, remaining on the edge of the holes and hiding very quickly at the slightest noise." Although they are extremely sensitive to movement, my own observation and experiments indicate that noises (excluding, of course, their own stridulation) have absolutely no effect on them.

Daily Schedule: The following notes are based chiefly upon observations at Bahia Honda, Panama, on a large colony living on light sand. The beach is close to the mouth of the bay, but protected from the full strength of the surf by an island close to shore. The holes as usual were all in the upper third of the beach, and covered at high tide.

These crabs are decidedly diurnal, and their daily routine is similar whatever their habitat. An individual, upon emergence from his hole near high tide line as the water recedes, is apparently very tired, and sits beside its hole, obviously resting, leaning first on one side, then on the other. At the slightest disturbance, even the close approach of a neighboring crab, it will reenter its hole. However, hermit crabs sometimes come up and touch a recently emerged *Ocypode* without the latter's paying the slightest attention. After some minutes' rest, during which some of the clinging sand has dried and fallen off, the crab cleans itself thoroughly, beginning with the polishing of the eyes with the palp of the third maxilliped. Not until almost an hour has passed do the largest crabs start toward the edge of the tide to feed. At first they walk slowly, then more rapidly, and at last gain their usual racing gait.

Feeding is carried on just in advance of the tide for an hour or more. Then the crabs return to the upper beach. (It is not yet certain that they return to the same holes they occupied during the preceding high water.) In any case each crab finds itself a burrow, which it repairs or enlarges according to its needs, or, rarely, it digs a new one. This work is punctuated with periods of feeding close to the hole. Sometimes there is still time after burrow repairs to feed at a distance again. Then the crabs gradually retire to their burrows, usually pulling in a plug of sand after them, until, fifty minutes to an hour before high tide, not a crab is left on the beach.

An interesting relationship was noted at Honda between the crabs and a nocturnal hermit

crab, not yet identified. This crustacean often was seen to come down from the jungle and enter the recently vacated hole of a beach crab, pull in a plug of sand, and spend the rest of the day, including, apparently, the succeeding high tide, if darkness did not fall before. *Ocypode* returning from the lower beach to find holes were never seen to pay the least attention to these newly occupied burrows, and no crabs appeared to be lost, or searching, in their vicinity. It may be that *Ocypode*, on broad beaches such as this, where they feed far from their holes, do not have a sense of property in regard to their burrows, once they have abandoned them after high tide, whereas crabs on narrow beaches, never straying far, may inhabit the same holes day after day.

O. gaudichaudii, as has been said, is active only during the day. In Panama City, on two nights, one brilliantly moonlit and the other dark, visits were made to the quite deserted beach where these crabs were numerous during the day. Although the holes had been opened by the crabs since the high tide (which fell after dark in each case), still not a crab had been feeding, as shown by the complete absence of pellets. The crabs themselves were usually found to be near the top of their sloping burrows, apparently asleep, since they were dug out without difficulty, whereas in daylight they always had to be dug from the very bottom of the long burrow.

The following is a typical time table of their daily activities, worked out from several days' observations on the broad beach at Bahia Honda. Sporadic observations made elsewhere agreed with these.

<i>Hours After High Tide</i>	
½	First young crabs emerge. (Since holes are not deep, tide leaves them first.)
1	First large crab emerges.
2	First large crab goes down to water's edge.
2-6	Migration of crabs to water's edge; the largest last, since they have deepest holes.
<i>Hours Before High Tide</i>	
3-1	Most crabs redigging holes and feeding intermittently around holes and at water's edge.
1	Last crab in hole. Largest are last to descend.

Obviously, this program can be carried out without postponement, interruption or curtailment due to darkness only when high tide is in the early morning or late afternoon. At Panama City, where there are exceptionally high tides, some members of a colony inhabited burrows which were not covered by neap tides. These individuals apparently spent most of their time quiescent in their holes during these periodic "droughts." More study is needed on this subject.

Material: In addition to the zoeae and mega-

lopa recorded in a previous paper (Crane, 1940,² pp. 67, 70), a total of 55 specimens of *O. gaudichaudii* was taken by the Eastern Pacific Zaca Expedition in the following localities: Meanguera I., Gulf of Fonseca, El Salvador (Cat. No. 37,677); Corinto (37,736) and San Juan del Sur (3838), Nicaragua; Port Parker (3857), Port Culebra (38,141), Piedra Blanca Bay (38,198), Uvita Bay (38,442), Golfito (38,529) and Parida Island (38,651), Costa Rica; Bahia Honda (38,682), Panama; Gorgona Island (38,838), Colombia. In addition, 11 specimens were taken in Panama City, Panama, in February, 1941 (Cat. No. 4150).

Ocypode occidentalis Stimpson.

Text-figs. 3; 4 E, F; 5 A, C, E, G; 6 A, C; 7 A, B; Pl. II, Fig. 5.

References: *Ocypoda occidentalis* Stimpson, 1862, p. 229. *Ocypode occidentalis*, Rathbun, 1917, p. 372, pl. 129, figs. 2, 3; Rathbun, 1923, p. 632; Boone, 1929, pp. 562, 580, fig. 16; Crane, 1940, p. 70, text-figs. 3-8.

Range: Turtle Bay, west coast of Lower California, to Peru.

Local Distribution: Almost always found on unprotected beaches which are beaten by heavy surf. Occurs rarely on outer beaches somewhat protected by mud flats.

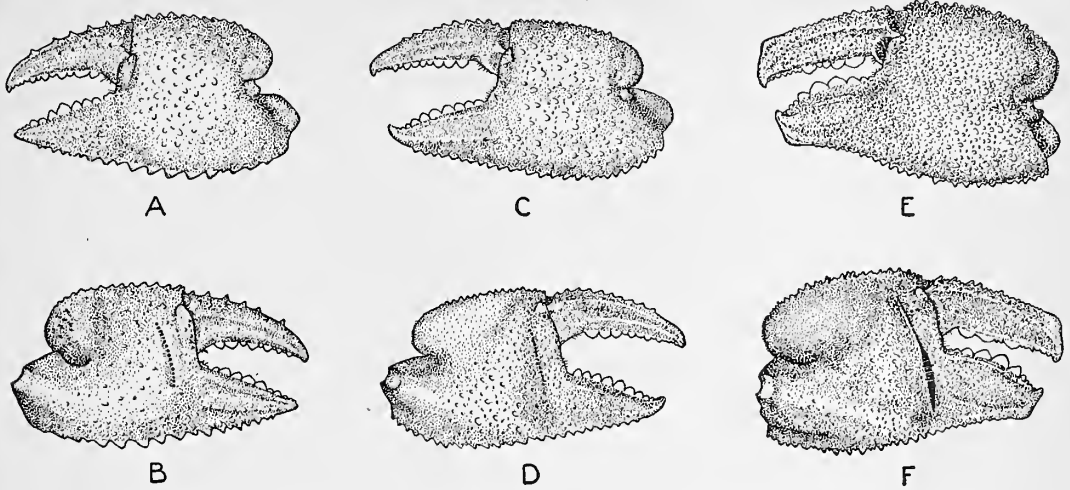
Size: The 35 specimens in the present collection measure between 3.9 and 24.5 mm. in length of carapace. The male co-type measured 43.2 mm. long.

Color: This species is much less highly colored than *gaudichaudii*, being always very pale, and always found on light sand. The carapace and legs of adults show marblings of gray and white on olive; the joint between merus and carpus of chelipeds is darkest, usually brownish; manus of chelipeds, all dactyls and underparts white.

The young are much more boldly patterned, with dark brownish-gray or even black marblings and splotches on olive buff. Legs banded irregularly with dark brown and gray. In the smallest there is a spot of scarlet in the middle of the posterior gastric region, and another on the merus of the last three pairs of ambulatories. In specimens of around 10 mm. in length, the red spots remain only on the gastric region and the most posterior ambulatory. In large crabs, measuring around 20 mm. or more, no trace of scarlet is found.

Early Crab Stages: Excluding the remarks concerning the specialized ocular stiles and chelae, the account of the young stages of *gaudichaudii* (p. 299 ff.) applies equally well to the present species, except that the stridulating ridge is not discernible in *occidentalis* until a length of about 6 mm. is reached. As shown in the key (p. 299), the young of the two forms may be distinguished

² In this paper reference was inadvertently omitted to Kemp's (1915) quotation of Annandale's notes concerning the behavior of the megalopa of *O. macrocera*. Dr. Annandale found that they made rudimentary burrows under the shelter of beached catamarans, became pale in strong light, and that they were preyed upon by adult crabs and, apparently, by ants. (Kemp, "Fauna of the Chelka Lake, Crustacea Decapoda," *Mem. Ind. Mus. Calcutta* 5, 1915, pp. 219-220, text-fig.)



Text-figure 7.

Major chelae of adult males in *Ocypode*. A, *occidentalis*, outer side; B, same, inner side; C, *albicans*, outer side; D, same, inner side; E, *guadichaudii*, outer side; F, same, inner side. All $\times 1.6$.

by their coloration when alive and, when preserved, by the proportions of the ischium of the third maxilliped. From a phylogenetic point of view, it is interesting that in young *occidentalis* the orbital angles are even less advanced than in adults of the Atlantic species, *albicans*, although in adult *occidentalis* the reverse is true. Specimens measuring around 20 mm. in length appear to be mature. None of the few large specimens in the present collection seems to be near breeding condition.

General Habits: This species is clearly the analogue of the Atlantic *albicans*, and their habits turn out to be very similar, while utterly dissimilar to those of *gaudichaudii*. Like the Atlantic form, the present species is wholly nocturnal when adult, although the young are also active during the day. They are typical predators and scavengers at all ages.

The alimentary canals of twelve specimens were examined, from crabs measuring between 6 and 25 mm. in length, taken in eight different localities. The contents were distributed as follows: Amphipods were present in four specimens, beetles in four, seaweed in three, worms (setae and jaws) in two, Thysanura in two, a minute sea urchin in one, and one was empty. In four a few sand grains were mixed with the organic matter.

Material: In addition to the megalopa recorded in a previous paper (Crane, 1940, p. 70), a total of 35 specimens of *O. occidentalis* was taken by the Eastern Pacific *Zaca* Expedition in the following localities: Banderas Bay (Cat. No. 37,132), Chamela Bay (37,165), Tenacatita Bay (37,199), Acapulco (37,278), and Port Guatulco (37,445), Mexico; Gulf of Fonseca near Potosi River (37,702) and Corinto, Nicaragua; Port Culebra (38,125), Costa Rica; Bahia Honda (38,698), Panama.

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EXPLANATION OF THE PLATES.

PLATE I.

- Fig. 1. *O. gaudichaudii*. Buccal frame of adult female, carapace length 25 mm. E marks enlarged endite of first maxilliped. Bahia Honda, Panama. $\times 3.5$.
- Fig. 2. *O. occidentalis*. Buccal frame of adult female, carapace length 24.5 mm. Port Guatulco, Mexico. $\times 3.5$.

PLATE II.

- Fig. 3. *O. gaudichaudii* beside burrow, with heap of excavated sand, feeding pellets and scraping

marks of truncate chelae. Bahia Honda, Panama.

- Fig. 4. *O. gaudichaudii*. Right abdominal appendage, right lateral view. Carapace length 25 mm. Panama City, Panama. $\times 6.6$.
- Fig. 5. *O. occidentalis*. Right abdominal appendage, right lateral view. Carapace length 25 mm. Chamela Bay, Mexico. $\times 9.2$.
- Fig. 6. *O. albicans*. Right abdominal appendage, right lateral view. Carapace length 24.5 mm. Bermuda. $\times 6.4$.



FIG. 1.

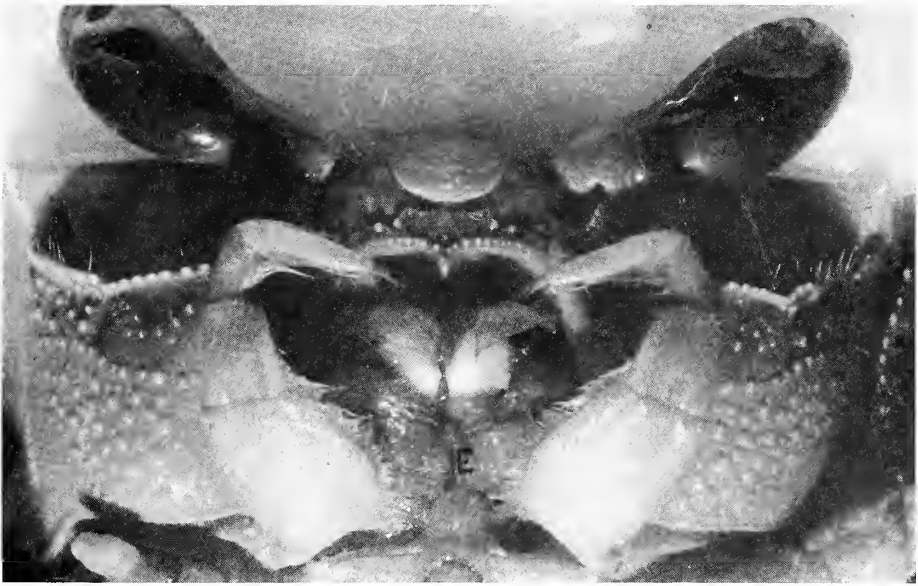


FIG. 2.

ON THE GROWTH AND ECOLOGY OF BRACHYURAN CRABS OF THE
GENUS OCYPODE



FIG. 3.



FIG. 4.



FIG. 5.



FIG. 6.

ON THE GROWTH AND ECOLOGY OF BRACHYURAN CRABS OF THE GENUS OCYPODE.

30.

High Speed Photographs of Flying Fishes in Flight.

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(Plates I-VIII).

INTRODUCTION.

The study of the mechanism of flight of the Exocoetidae has long been handicapped by a lack of good photographs of the performance. Such knowledge as we have of the factors involved has been based on simple observation and the interpretation of studies on the morphology of the Exocoetidae. That this was still in a not altogether satisfactory state led Breder (1937 and 1938) to remark rather sharply about the general attitude on the problem. Further no one can deny that there are still a host of details, a knowledge of which would be both of practical aerodynamic and academic value.

The first satisfactory photographs of flying fishes in various stages of flight are presented herewith with such interpretations as may be made from them. The photographs were taken on the east coast of Catalina Island, California, at night, during July, 1940, by one of the authors, Edgerton. They all represent the species *Cypselurus californicus* (Cooper) and are all results of the high-speed electrical flash photography method developed at the Massachusetts Institute of Technology. The value of this device for biological pursuits concerning locomotor matters involving high speeds is obvious. See Edgerton & Killian (1939) for a comprehensive bibliography on technique. If it had been practicable, high-speed motion pictures would have been even more valuable and it is to be hoped that such may be made in the future. As it is the stills presented herewith show a host of items unsuspected and illuminate a variety of others which for long have resided in the limbo of half-knowledge. The time of exposure in all cases is about 1/10,000 of a second, which is sufficiently short to "stop" all motion.

Acknowledgment is made of the splendid co-operation of the Catalina Island Company which furnished the motor boat *Blanche W.* This ship is equipped with a 110 volt D. C. generator and search light for observing the flying fishes at night. A small converter was used to produce alternating current to operate the electrical flash equipment. Two flash lamps were used in parallel. One of these was an experimental lamp about four feet in length (in two sections) in a cylindrical reflector. The other was a spiral lamp in a spherical reflector that was loaned for the occasion by the Los Angeles *Herald-Express*.¹ The straight tube was mounted on a pipe-work frame as far out over the water as possible, while the other was hand-held and directed at the fish that was photographed. A miniature Speed Graphic camera was used. A photograph is shown of the entire arrangement on the foredeck of the *Blanche W* in Plate I, Fig. 1.

ANALYSIS OF PLATES.

The details which these photographs show are analyzed in the following section while the resulting interpretations are given under the heading "Discussion," both the remarks and interpretations being those of Breder.

Plate II, Fig. 2. The fish in full flight. Since the right pectoral is evidently arched upward near its center of pressure it would appear that the fish is rolling to that side with the left pectoral high. At the same time the tail is being swung to the right as is evidenced by the weaker central rays bending to the left. This would then represent normal resistance to extrinsic turning with banking to the right. Since the effects are

¹ This second lamp is the same as the Eastman Kodak Speedlamp.

both slight, as is evident, it should represent an incipient turn of large radius which is being corrected. It may be noted that the right pelvic also appears to be pressed upwards with the left normal. The dorsal fin so far as can be seen in this picture seems unaffected. This shows well the extent of expansion of the wing surfaces under actual flight. Dead and preserved material give the impression of much less wing area due to shrinkage of the delicate membrane between the supporting ribs.

Plate III, Fig. 3. Just before emergence the paired fins may be seen closely appressed to the sides, while the upper caudal lobe already raises a wake, throwing spray high in the air before the head of the fish breaks the surface.

Plate III, Fig. 4. Similar to Fig. 3 but with even greater spray throwing and the fish describing a curve. It is doubtful if this attempt actually lead to a flight.

Plate IV, Fig. 5. Two fish just at emergence. The pectorals are lifted but the pelvics seem to be only about half extended. At the extreme left are to be seen the first few flicks of spray raised by the upper caudal lobe. The emergence of the snout and body is represented by the heavy mass of spray. Note the extent of travel by the fish before the earliest spray has fallen.

Plate IV, Fig. 6. Full lateral view of a fish just before taking off. Both pectorals show a large amount of arching due to the pressure on them just before flying speed is obtained. The pelvics are only partly, if at all, unfolded. When this occurs the tail lifts and the greater amount of supporting surface relieves the load on the pectorals.

Plate V, Fig. 7. A diagonal view of a fish about to take off. The one visible pelvic appears to be about one-half expanded. Note the zigzag track which marks the "taxi" period and gives some idea of the value of each tail thrust in terms of the fish's length.

Plate VI, Fig. 8. A fish coming head on while in the "taxi" period. Apparently the pelvics are still being held close to the body for, if otherwise, in this photograph they should be conspicuous. As usual during this time the fish appears to be rolling badly, at the moment bearing down on the right pectoral and lifting the left. As some measure of the vigor of this rolling movement the flexible posterior margin of this fin is clearly bending down as the fin presses upward. It is this rolling that has given rise to the oft-repeated claim of wing flapping flight in these fishes.

Plate VII, Fig. 9. A fish just having cleared the water and steadying off to a smooth glide. The pelvics are still at a sharp angle pressing the tail upward. A moment later they would be approximately parallel to the pectorals.

Plate VII, Fig. 10. A second view of essentially the same position as that of Fig. 2 but not as marked a turning. The left pectoral of this fish has been damaged on its posterior border. Another specimen in the background is just

leaving the water with the long lower caudal lobe still immersed.

Plate VIII, Fig. 11. A fish not quite maintaining flying speed. The body is somewhat arched in a vertical plane anticipatory to the tail's touching the surface of the water, when the "taxi" stage will be resumed and flight continued without complete submergence.

DISCUSSION.

The photographic evidence here recorded is in good agreement with recent descriptive interpretation, *e. g.* Breder (1930), Hubbs (1933, 1935 and 1937), Carter & Mander (1935), Forbes (1936), and Loeb (1936). Reference to these papers shows that nearly all of the descriptive details given by them are evident from these photographs. In addition there are a number of items that could not be made out by field observation or interpretations based on anatomical study.

For example, in Figs. 6, 7 and 8 it may be seen that the mouth is held open. In all the others this feature cannot be distinguished because of position or some other reason. If this can be taken to mean that flying fishes usually or normally hold their mouths open during flight it is to say the least surprising. Even that they ever do was not expected. Two reasons for holding the mouth closed would be to preserve intact the streamline form of the head and to prevent the desiccating effect of a current of air passing over the delicate gill membranes. However this may be it is clear that these fishes do not always preserve form and conserve moisture by this simple expedient.

The two pictures of Plate III showing the fishes completely submerged and swimming nearly parallel with and very close to the surface indicate another unexpected feature; that of throwing spray with their tails before breaking the surface. All this happens so quickly that under mere ocular observation it is normally lost in the general flurry of the fish's plunging out into the air. Checking back, however, the proportions of these fish are such that the upper caudal lobe would project through the surface if they were swimming close to and parallel to it. Actual measurements show that the tail tip of a *Cypselurus californicus* 12 inches in standard length is a little over $\frac{3}{4}$ inch above the level of the flat back while the dorsal fin when erect is not quite $\frac{1}{2}$ inch above the back. In other words a fish 12 inches long would be just breaking the surface film with its tail tip when swimming with $\frac{3}{4}$ inch of water over its back. This would seem to indicate that these fishes travel in this fashion just prior to emerging for some little distance, for otherwise it would be very unlikely that the photographer could get such photographs at all. Their sometimes apparent relatively steep angle of emergence is then probably generally due to the rapid tip up of the snout as the unfolding wings encounter air resistance. An angle of emergence of more than about 4° would prevent the tail and dorsal from breaking

the surface before the snout came out. Incidentally these photographs show very good agreement with the sketches of Hubbs (1933).

In considering the various flexures of the fin rays that are shown in these photographs it must be borne in mind that these are long, thin, more or less flexible rods that are attached only at their bases and there operated by relatively small muscle bundles. Since the fish can only wave these rods about in various ways, mostly backward and forward and to a lesser degree up and down and since they have no voluntary control over the curvature of them it follows that the contortions shown are the result of wind pressure. This being the case the interpretation of the meaning of the curves seen becomes relatively simple. Even, as in these cases, where we have no direct knowledge of what the fish was doing before or after the instant of exposure, these curves, as indicated under "Analysis of Plates," give clues as to what the fish was undertaking.

In Fig. 11, for example, it is clear that the fish is descending and is all set for a renewal of the "taxi" period. Note that the wings are relatively straight and show a large lateral dihedral, for stability, while in Fig. 6, where the fish is driving ahead under the impulse of powerful tail thrusts, the wings held at a lower angle (see the basal part) are actually blown back and up and cupped by wind pressure. In other words they are loaded relatively more heavily than, as in Fig. 11, where the fish is merely falling freely.

Many other points already fairly well understood are reinforced by the details in these photographs. The next logical step looking toward a further clarification of exocoetid flight would be the application of high-speed cinematography whereby actual series of steps in this performance could be studied. Carter & Mander (1935) used motion picture technique to check the speed of flight but presumably they obtained a very small image not of value in studying details of manipulation of the fishes' structures.

Recently Woodcock (1940a and 1940b) has discussed the instability of air over the ocean showing that bands of updraughts occur, by an ingenious noting of the differential behavior of soaring gulls. These bands are responsible for the lines of Sargassum commonly found in the Atlantic according to the studies of Langmuir (1938). Since exocoetids may fly in a straight line or in various curving flights it may well be that these too are taking advantage of such atmospheric characteristics instead of merely

being blown off their course as has been generally assumed. Carter & Mander (1935) indicated that they found their fish flying greater distances over rough water than over smooth and inferred that advantage was taken of the greater air turbulence in the former condition. Hubbs (1933 and 1936) could not find a difference in duration of flight to be correlated with travel over smooth or rough water. In any case the situation calls for a study of the flight of these fish in the light of the work of Woodcock on gulls and in reference to the general recent advances of micrometeorology.

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EXPLANATION OF THE PLATES.

Photographs by Dr. H. E. Edgerton. Taken at night by means of a Kodatron type of electrical flash lamp. Photographs all unretouched. All specimens are *Cypselurus californicus* (Cooper).

PLATE I.

Fig. 1. The photographic equipment and its arrangement as used for taking pictures of flying fish in flight.

PLATE II.

Fig. 2. A fish in full flight. The object in the upper left corner is part of the special illuminating device.

PLATE III.

Fig. 3. Just before emergence, showing that the water is splashed before the fish breaks the surface.

Fig. 4. A more advanced stage in the water splashing period.

PLATE IV.

Fig. 5. Two fish just about to leave the water near the end of the "taxi" stage.

Fig. 6. Full lateral view of a fish in the "taxi" stage.

PLATE V.

Fig. 7. A diagonal view of an advanced "taxi." Note the trail left by the oscillating tail.

PLATE VI.

Fig. 8. Head on view of a fish in an advanced "taxi." Note the evidences of roll in the differentially warped wings.

PLATE VII.

Fig. 9. Just as the tail raises after the "taxi" stage.

Fig. 10. One fish in full flight in the foreground. Note the torn left wing. Another in the background with only the long lower caudal lobe immersed.

PLATE VIII.

Fig. 11. Losing flying speed and about to dip the tail in the water for a resumed "taxi."

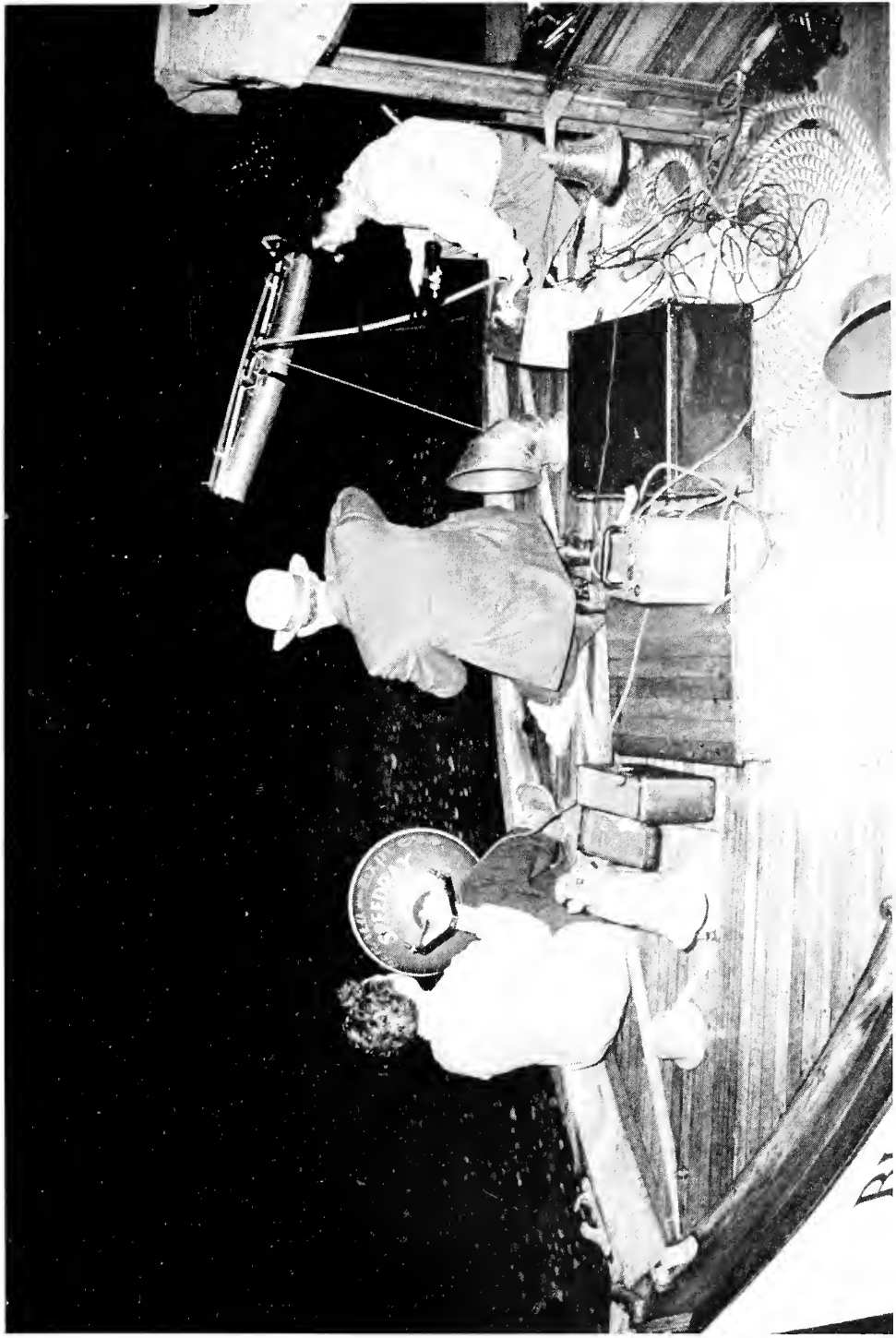


FIG. 1.

HIGH SPEED PHOTOGRAPHS OF FLYING FISHES IN FLIGHT

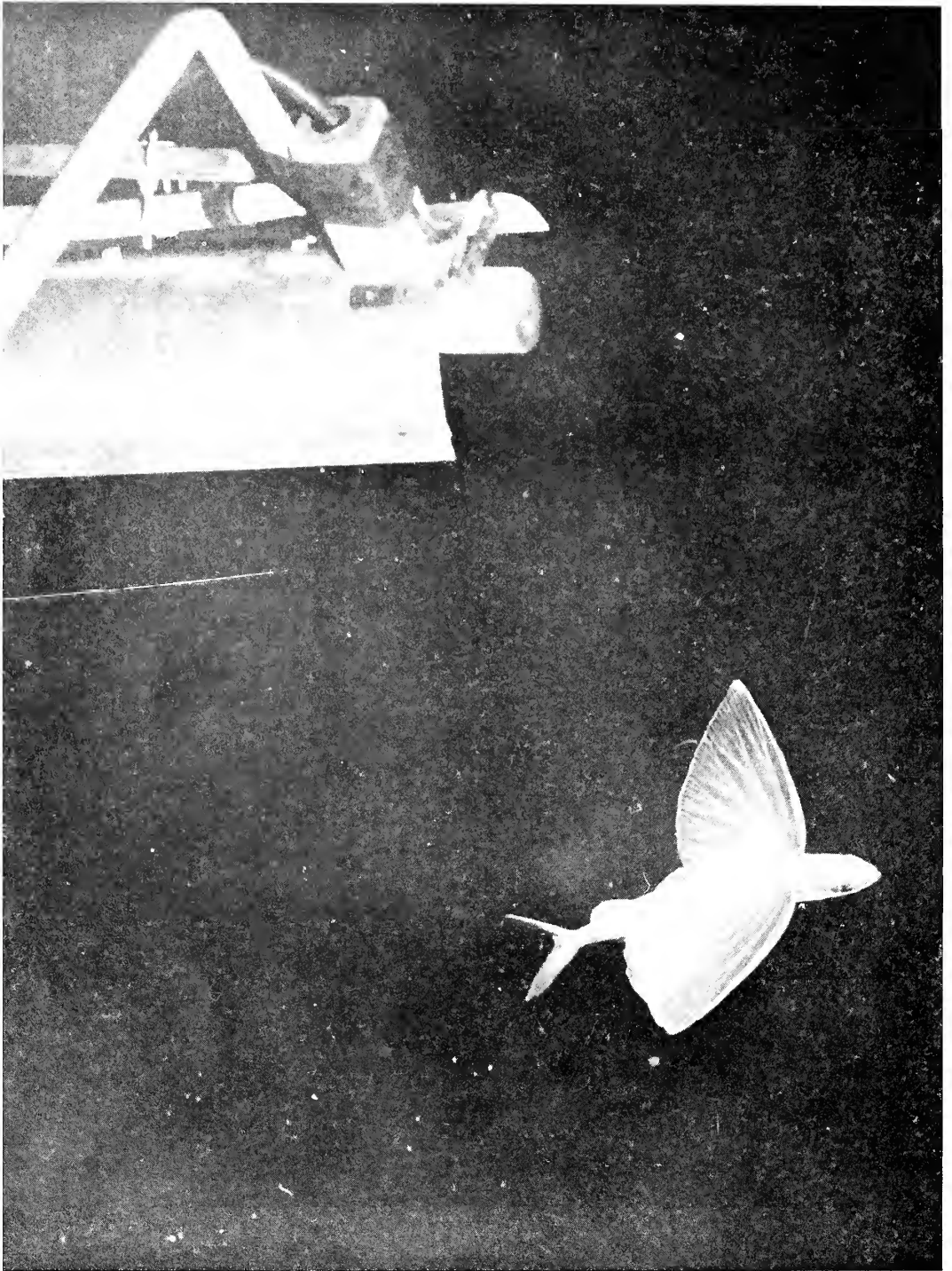


FIG. 2

HIGH SPEED PHOTOGRAPHS OF FLYING FISHES IN FLIGHT.

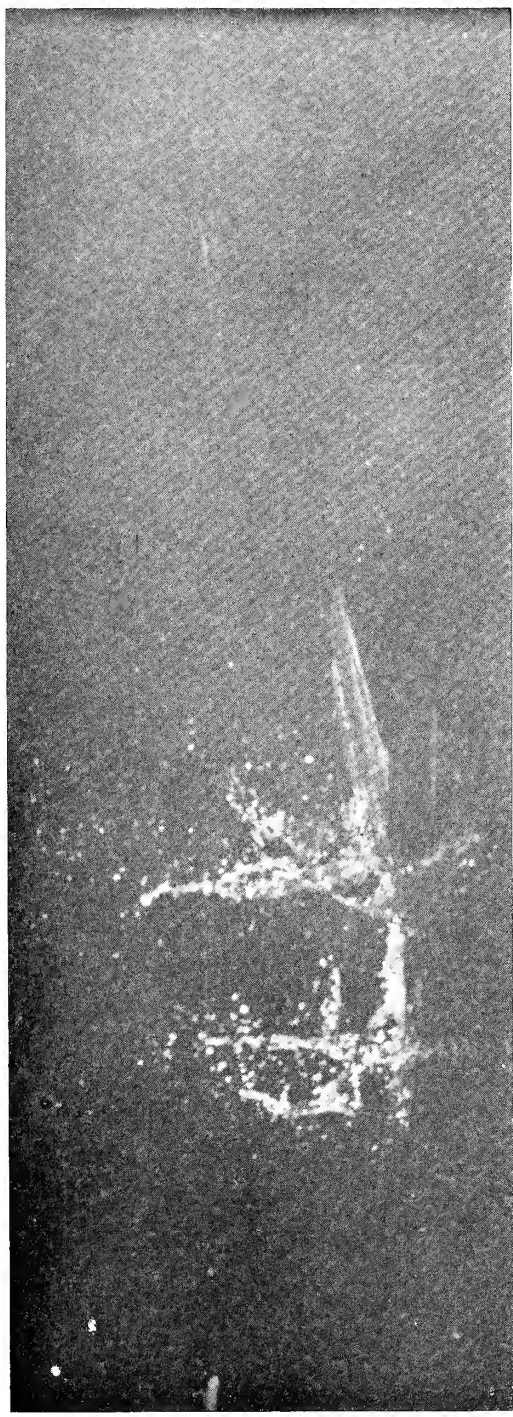


FIG. 3.



FIG. 4.
HIGH SPEED PHOTOGRAPHS OF FLYING FISHES IN FLIGHT

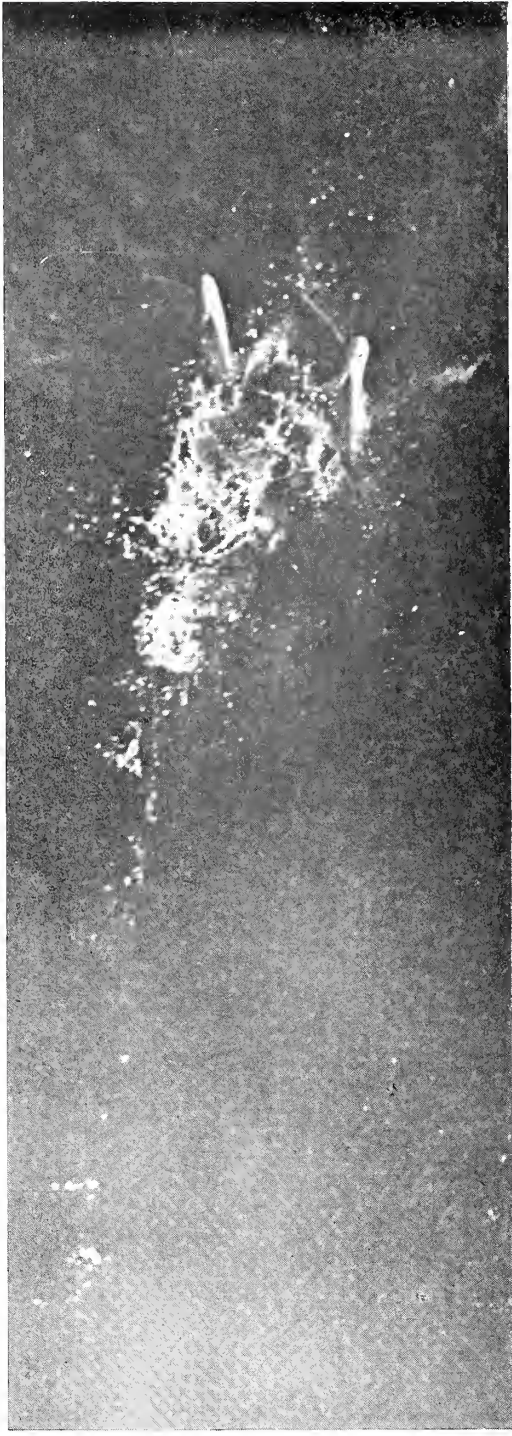


FIG. 5.



FIG. 6.
HIGH SPEED PHOTOGRAPHS OF FLYING FISHES IN FLIGHT



FIG. 7.
HIGH SPEED PHOTOGRAPHS OF FLYING FISHES IN FLIGHT



FIG 8

HIGH SPEED PHOTOGRAPHS OF FLYING FISHES IN FLIGHT.

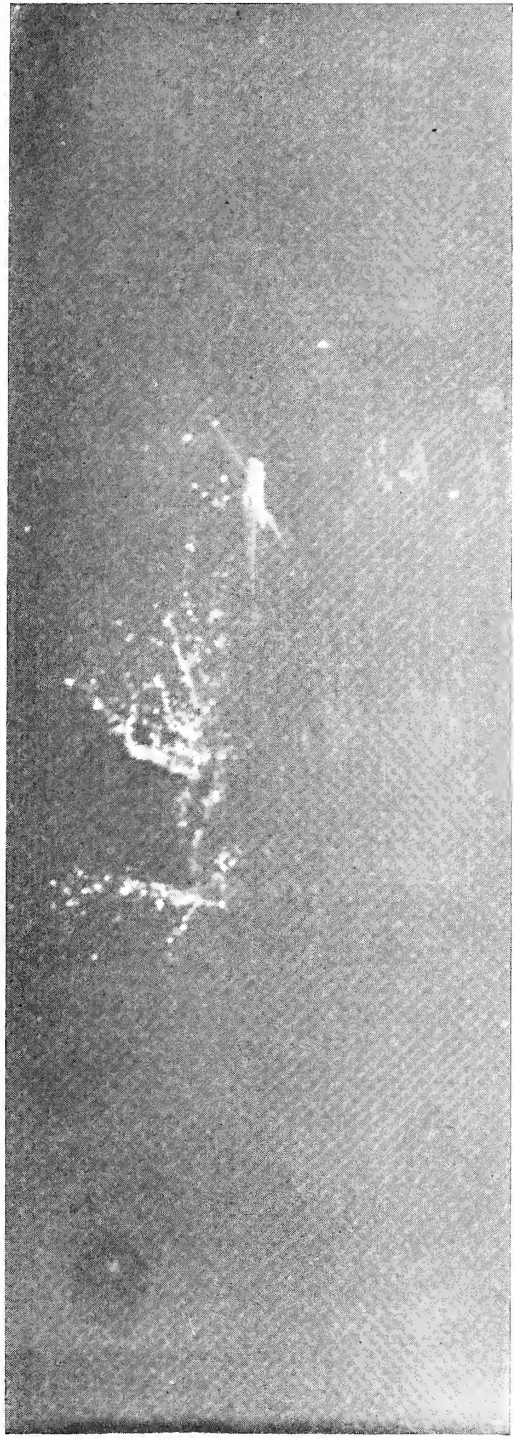


FIG. 9.

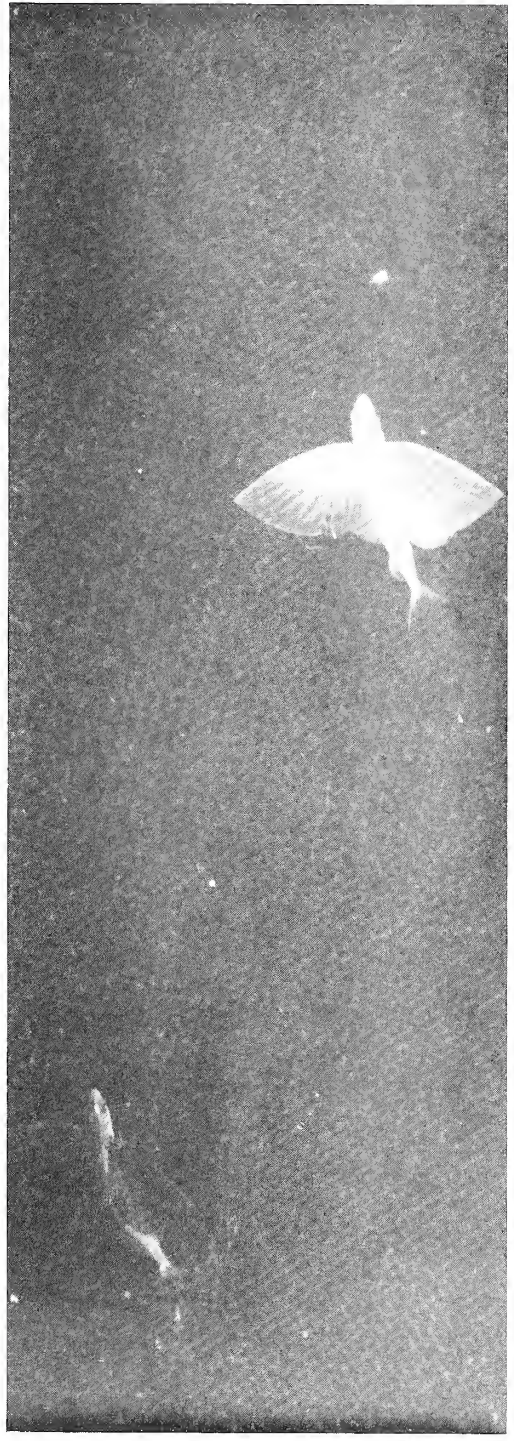


FIG. 10.
HIGH SPEED PHOTOGRAPHS OF FLYING FISHES IN FLIGHT.

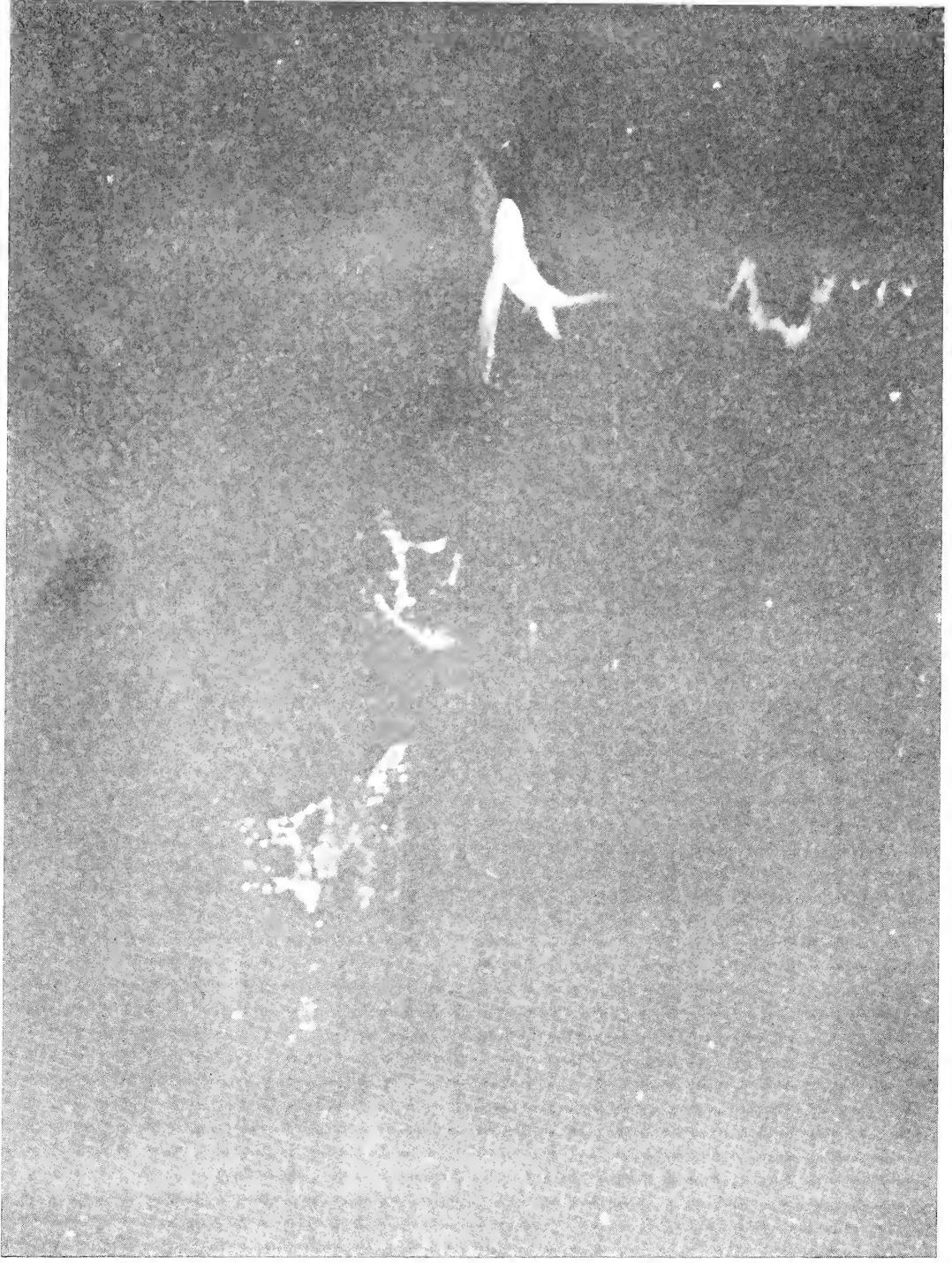


FIG. 11.
HIGH SPEED PHOTOGRAPHS OF FLYING FISHES IN FLIGHT.

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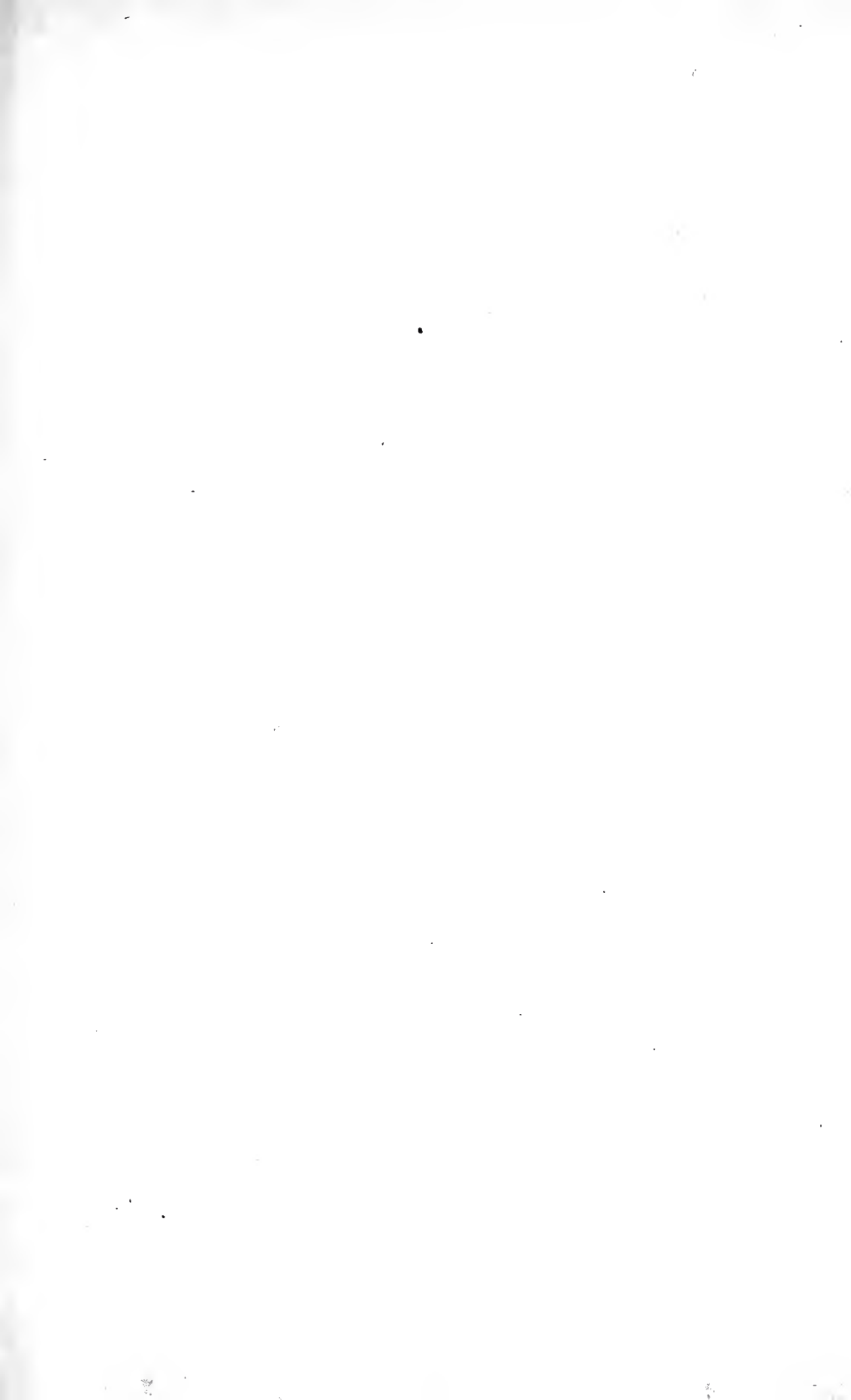
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